DECLARATION

In the matter of U.S. Patent Application Ser. No. 10/798,409 in the name of Kenji TSUKADA, et al.

I, Mariko ENDO, of Kyowa Patent and Law Office, 2-3, Marunouchi 3-Chome, Chiyoda-Ku, Tokyo-To, Japan, declare and say:

that I am thoroughly conversant with both the Japanese and English languages; and,

that the attached document represents a true English translation of Japanese Patent Application No. 2000-229435 filed on July 28, 2000.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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[Title of Invention] LIQUID CONTAINER AND METHOD OF MANUFACTURING THE SAME

[Claims]

[Claim 1]

A liquid container, characterized in comprising:

a container body that can be filled with a liquid;

a liquid feed port that can externally supply the liquid in the container body;

a piezoelectric device that can detect a consumption condition of a liquid in the container body; and

a liquid-philic part having a liquid-philic characteristic with respect to the liquid in the container body.

[Claim 2]

A liquid container according to claim 1, characterized in that:

the liquid-philic part includes a vibrating area on the piezoelectric device which comes in contact with the liquid in the container body.

[Claim 3]

A liquid container according to claim 1, characterized in that:

the piezoelectric device has a cavity that can open inwardly to the container body so as to come in contact with the liquid container, and

the liquid-philic part includes the inner side surface of the cavity.

[Claim 4]

A method of manufacturing a liquid container, characterized in comprising:

a step of preparing a liquid container comprising a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, and a piezoelectric device that can detect a consumption condition of a liquid in the container body;

a forming step of forming a liquid-philic part on the piezoelectric device, the

liquid-philic part having an affinity to the liquid in the container body,

an arranging step of arranging the piezoelectric device in the liquid container after the forming step.

[Claim 5]

A method of manufacturing a liquid container, characterized in comprising:

a step of preparing a liquid container comprising a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, and a piezoelectric device that can detect a consumption condition of a liquid in the container body;

an arranging step of arranging the piezoelectric device in the liquid container; and

a forming step of forming a liquid-philic part on the piezoelectric device after the arranging step, the liquid-philic part having a liquid-philic characteristic with respect to the liquid in the container body.

[Claim 6]

A method of manufacturing a liquid container, characterized in comprising:

a step of preparing a liquid container comprising a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, a piezoelectric device that can detect a consumption condition of a liquid in the container body, and a mounting structure for mounting the piezoelectric device into the liquid container,

an arranging of arranging the piezoelectric device in the mounting structure; and

a forming step of forming a liquid-philic part on at least the piezoelectric device, the liquid-philic part having a liquid-philic characteristic with respect to the liquid in the container body after the arranging step; and

a mounting step of mounting the mounting structure into the container body after the forming step.

[Claim 7]

A method of manufacturing a liquid container, characterized in comprising:

a step of preparing a liquid container comprising a container body that can be

filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, a piezoelectric device that can detect a liquid consumption condition in the container body, and a mounting structure for mounting the piezoelectric device into the liquid container,

a forming step of forming a liquid-philic part on at least the piezoelectric device, the liquid-philic part having a liquid-philic characteristic with respect to the liquid in the container body;

an arranging step of arranging the piezoelectric device in the mounting structure after the forming step; and

a mounting step of mounting the mounting structure into the container body after the disposing step.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a liquid container provided with a piezoelectric device that can detect a liquid consumption condition in the liquid container that can be filled with a liquid by detecting changes in an acoustic impedance, particularly by detecting changes in a resonance frequency and a method of manufacturing the liquid container, more specifically, the present invention relates to a liquid container that can be applied to an ink jet recording apparatus, which pressurizes ink in a pressure generating chamber by a pressure generating means according to printing data thereby jetting an ink drop from a nozzle to perform printing, and a method of manufacturing the liquid container.

[0002]

[Description of the Related art]

For example, an ink cartridge mounted in an ink jet recording apparatus will be described as a liquid container according to the present invention. Generally, in an ink jet recording apparatus, an ink jet recording head having: a pressure generating means that can pressurize a pressure generating chamber; a nozzle that can jet pressurized ink as an ink drop, mounted on a carriage; and an ink tank that can be filled with ink to be

supplied to the recording head through a flow path so as to permit continuous printing. The ink tank is generally structured as a cartridge removable from the recording apparatus that can be simply exchanged by a user when the ink is consumed.

[0003]

Examples of ink consumption control methods of an ink cartridge include: a method for totalizing the number of ink drops jetted by the recording head and the ink amount sucked at the maintenance step of a print head by means of some software and controlling the ink consumption from calculation; and a method for attaching two electrodes for detecting a liquid level to the ink cartridge, detecting the point of time when the ink is actually consumed by a predetermined amount, thereby controlling the ink consumption.

[0004]

However, in the method for totalizing the number of jetted ink drops and the sucked ink amount by the software and controlling the ink consumption from calculation, unnegligible errors may be caused between the ink consumption from calculation and the actual consumption. Further, when a cartridge is once removed and then mounted again, an accumulated count value is reset and therefore, an actual amount of ink remaining in the cartridge cannot be known at all.

[0005]

On the other hand, in the method of controlling the point of time of ink consumption by the electrodes, a problem arises that the liquid tight structure between the electrodes and the ink cartridge is complicated. Furthermore, as a material of the electrodes, a noble metal which is enough conductive and highly corrosion-resistant is ordinarily used, so that a problem also arises that manufacturing cost of an ink cartridge is increased. Furthermore, two electrodes must be mounted at different parts of the ink cartridge, so that many manufacturing steps are required.

[0006]

On the other hand, there is a method of using a piezoelectric device that can detect a consumption condition of a liquid in a liquid container that can be filled with a liquid by detecting changes in an acoustic impedance. This method does not cause the above problems.

[0007]

[Problems to be Solved by the Invention]

However, in the method using a piezoelectric device to detect a consumption condition of a liquid in a liquid container that can be filled with a liquid by detecting changes in an acoustic impedance, the piezoelectric device comes in contact with ink to detect the liquid surface of the ink. Therefore, when the ink is consumed and the liquid surface level lowers below the position of the piezoelectric device, the liquid container swings and the liquid waves due to a reciprocating motion of the carriage and a liquid drop adheres to a vibrating area, then, the piezoelectric device may misdetect existence of the ink although there is no ink. Further, when an ink drop adheres to the inner wall surface of the ink cartridge then flows down adheres to the piezoelectric device by mistake, there is a possibility of a similar misdetection.

[0008]

Further, when the ink is filled at the time of manufacture or recycle of the ink cartridge, if the ink is not brought into contact with the piezoelectric device fully, the piezoelectric device sometimes detects that there is no ink even though the ink cartridge is filled with the ink. This ink cartridge is treated as a faulty one.

[0009]

Further, from the viewpoint of the reuse of resources, when the ink in the ink cartridge is consumed and a remaining amount of the ink is small, it is preferable that the ink cartridge can be easily refilled with the ink. Furthermore, it is more preferable that the empty ink cartridge can be recharged with the ink for recycling. It is also desired that the inside of the ink cartridge can be easily cleaned at the time of recycling of the ink cartridge.

[0010]

Accordingly, an object of the present invention is to provide a liquid container that can be filled and refilled easily with ink when the ink is brought in contact with the piezoelectric device fully at the time of manufacturing or recycling of the container body so as to improve the reliability of the liquid container.

[0011]

A further object of the present invention is to provide a liquid container wherein a

piezoelectric device does not misdetect whether a liquid exists or not.

[0012]

A furthermore object of the present invention is to provide a liquid container that can be easily recycled by refilling the empty liquid container with a liquid.

[0013]

A furthermore object of the present invention is to provide a liquid container of which inside can be easily cleaned at the time of recycling of the liquid container.

[0014]

These objects can be attained by a combination of the characteristics described in the independent claims in the range of the claims. Further, the dependent claims specify further advantageous specific examples of the present invention.

[0015]

[Means for Solving the Problems]

That is, a liquid container of an embodiment according to the present invention comprises a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, a piezoelectric device that can detect a liquid consumption condition in the container body, and a liquid-philic part having a liquid-philic characteristic with respect to the liquid in the container body. It is preferable that the liquid-philic part includes a vibrating area on the piezoelectric device which comes in contact with the liquid in the container body.

[0016]

The piezoelectric device may have a cavity which opens inwardly to the container body so as to come in contact with the liquid container. In this case, the liquid-philic part includes the inner side surface of the cavity.

[0017]

The piezoelectric device may have a substrate for mounting a material having a piezoelectric characteristic into the container body. In this case, it is preferable that the liquid-philic part includes a part of the substrate which comes in contact with the liquid in the container body.

[0018]

The liquid-philic part may include a mounting structure for mounting the piezoelectric device into the container body. The liquid-philic part may be the whole part of the liquid container which comes in contact with the liquid in the container body. It is preferable that the contact angle of the liquid-philic part with the liquid in the container body is not more than 30 degrees.

[0019]

At least the periphery of the liquid-pihlic part in the liquid container according to the present invention may have a liquid-phobic characteristic with respect to the liquid in the container body. It is preferable that the contact angle of the liquid-philic part with the liquid in the container body is not more than 30 degrees and the contact angle of the liquid-phobic part and the liquid in the container body is not less than 60 degrees.

[0020]

The liquid-philic part may be formed by being coated with a material having a liquid-philic characteristic with respect to the liquid in the container body. The liquid-philic part may be formed with a material having a liquid-philic characteristic with respect to the liquid in the container body. The liquid-philic part may be formed by subjecting a predetermined material to a surface-roughening treatment. The liquid-philic part may be formed by irradiating ultraviolet rays onto the predetermined material.

[0021]

It is preferable that the piezoelectric device detects at least an acoustic impedance of a medium in the container body and detects a liquid consumption condition based on changes of the acoustic impedance. It is preferable that the piezoelectric device is further provided with a vibrating part which vibrates and detects a liquid consumption condition based on a counter electromotive force generated by residual vibration remaining in the vibrating part.

[0022]

It is preferable that the liquid container is mounted in an ink jet recording apparatus provided with a recording head for jetting an ink drop and supplies a liquid in a container to the recording head.

[0023]

In a method of forming a liquid-phobic part of an embodiment according to the present invention, a liquid-philic part having a liquid-philic characteristic with respect to a liquid in a container body is formed in a liquid container, the liquid container comprising a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, and a piezoelectric device that can detect a liquid consumption condition in the container body.

[0024]

The above method may comprise a covering step of covering the material with a material having a liquid-philic characteristic with respect to the liquid in the container body.

[0025]

In the covering step, the material may be covered with a material having a liquid-philic characteristic with respect to the liquid in the container body by immersing the target material into the material having a liquid-philic characteristic with respect to the liquid in the container body in advance.

[0026]

In the covering step, the material may be covered with a material having a liquid-philic characteristic with respect to the liquid in the container body by coating the target material with the material having a liquid-philic characteristic with respect to the liquid in the container body.

[0027]

In the covering step, the material may be covered with the material having a liquid-philic characteristic with respect to the liquid in the container body by applying a film layer having a liquid-philic characteristic with respect to the liquid in the container body onto the target material.

[0028]

In the covering step, the material may be covered with a material having a liquid-philic characteristic with respect to the liquid in the container body by depositing the material having a liquid-philic characteristic with respect to the liquid in the container

body onto the target material.

[0029]

In the covering step, the material may be covered with the material having a liquid-philic characteristic with respect to the liquid in the container body by plating the target material with the material having a liquid-philic characteristic with respect to the liquid in the container body.

[0030]

The method may comprise a forming step of forming a liquid-philic part by using the material having a liquid-philic characteristic with respect to the liquid in the container body. The method may comprise the forming step of forming the liquid-philic part by irradiating an ultraviolet light onto a predetermined material. The method may comprise the forming step of forming the liquid-philic part by subjecting the predetermined material to a surface-roughening treatment.

[0031]

Further, in a method of manufacturing a liquid container of an embodiment according to the present invention, a liquid container comprising a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, and a piezoelectric device that can detect a liquid consumption condition in the container body may be prepared, the piezoelectric device may be arranged in the liquid container after the formation of a liquid-philic part having a liquid-philic characteristic with respect to the liquid in the liquid container, and the liquid-philic characteristic with respect to the liquid in the liquid container may be formed on the piezoelectric device after the arrangement of the piezoelectric device in the liquid container.

[0032]

Further, in the method of manufacturing a liquid container of an embodiment according to the present invention, a liquid container comprising a container body that can be filled with a liquid, a liquid feed port that can externally supply the liquid in the container body, and a piezoelectric device that can detect a liquid consumption condition in the container body, and a mounting structure for mounting the piezoelectric device in the liquid container may be prepared,

the mounting structure may be attached to the container body after the arrangement of the piezoelectric device in the mounting structure followed by the formation of a liquid-philic part having at least a liquid-philic characteristic with respect to the liquid in the container body, and the mounting structure may be attached to the container body after the formation of the liquid-philic part, and the piezoelectric device may be arranged in the mounting structure and then the mounting structure may be mounted in the container body after the formation of the liquid-philic part having a liquid-philic characteristic with respect to the liquid in the container body at least on the piezoelectric device.

[0033]

In addition, the above summary of the invention does not enumerate all necessary characteristics of the present invention, but the subcombination of the group of these characteristics may also be an invention.

[0034]

[Description of the Preferred Embodiments]

The present invention will be explained hereunder with reference to embodiments of the present invention, however, the present invention defined only by claims is not limited to the embodiments described below, and combinations of characteristics explained in the embodiments are not always necessary.

[0035]

A basic strategy of the present invention is to detect a liquid condition in a liquid container (whether a liquid exists or not, a volume of the liquid, a surface level of the liquid, a kind of the liquid, composition of the liquid, and so on) by using a vibration phenomenon. Some methods have been developed as concrete methods for detecting a liquid condition in a liquid container by using a specific vibration phenomenon. There is a method of detecting a medium or a change in condition of the medium in a liquid container: for example, by generating an elastic wave toward an inside of the liquid container; and by receiving a reflected wave that is reflected by a liquid surface or an opposite wall. Further, other than the above method, there is also a method of detecting a change in acoustic impedance from a vibration characteristic of a vibrating object. As a method of using the change in the acoustic impedance, there is a method of detecting

a resonance frequency or an amplitude of a counter electromotive force waveform as the change in the acoustic impedance: by causing a vibrating part of a piezoelectric device having a piezoelectric member or an actuator to vibrate, and then by measuring the counter electromotive force generated by residual vibration remaining in the vibrating part and, alternatively, there is a method of measuring an impedance characteristic or an admittance characteristic of the liquid by means of a measuring instrument such as an impedance analyzer, for example, a transmission circuit, and measuring a change in a current value or a voltage value, or a change in a frequency of a current value or a voltage value when a vibration is given to the liquid.

[0036]

Fig. 1 is a cross-sectional view of one embodiment of an ink cartridge for a single color, for example, a black color to which the present invention applies. The ink cartridge shown in Fig. 1 is based on the method of detecting a resonance frequency or an amplitude of a counter electromotive force waveform as the change in the acoustic impedance: by causing a vibrating part of a piezoelectric device having a piezoelectric member or an actuator to vibrate, and then by measuring the counter electromotive force generated by residual vibration remaining in the vibrating part. An actuator 106 is used for a method of detecting changes in an acoustic impedance. A container body 1 that can be filled with ink is provided with an ink feed port 2 interconnected to an ink feed needle of a recording apparatus. The actuator 106 is mounted at the outside of a bottom surface 1a of the container body 1 so as to come in contact with the ink in the container body via a through hole 1c. Further, it is preferable that the actuator 106 is arranged on the side wall of the container body 1 so as to come in contact with the ink in the container body 1 via the through hole 1c. Furthermore, so as to change the medium in contact with the actuator 106 from the ink to a gas at a stage of almost consumption of the ink K, that is, at the point of time of an ink-near-end condition, the actuator 106 is installed at a position slightly above the ink feed port 2. In addition, it is possible to install a means for generating vibration independently and use the actuator 106 just as a detection means.

[0037]

In the ink feed port 2, a packing 4 and a valve body 6 are installed. Particularly, as

shown in Fig. 2, the packing 4 is liquid-tightly joined to an ink feed needle 32 interconnecting to a recording head 31. The valve body 6 is always contacted with the packing 4 elastically by a spring 5. When the ink feed needle 32 is inserted, the valve body 6 is pressed by the ink feed needle 32 to open an ink flow path, so that the ink in the container body 1 is fed to the recording head 31 via the ink feed port 2 and the ink feed needle 32. On the upper wall of the container body 1, a semiconductor storage unit 7 storing information concerning ink in the ink cartridge is mounted.

[0038]

Fig. 2 is a cross sectional view showing an embodiment of the main part of an ink jet recording apparatus appropriate for the ink cartridge shown in Fig. 1. A carriage 30 movable back and forth in a width direction of a recording paper has a subtank unit 33, and the recording head 31 is installed on the bottom of the subtank unit 33. Further, the ink feed needle 32 is installed on the ink cartridge loading side of the subtank unit 33.

[0039]

Fig. 3 is a drawing showing the actuator 106 as one embodiment of a piezoelectric device. The actuator mentioned herein is used for the method of detecting a consumption condition of a liquid in a liquid container by detecting at least a change in an acoustic impedance. The actuator is specifically used for the method of detecting at least a change in an acoustic impedance and a consumption condition of a liquid in a liquid container by detecting a resonance frequency by residual vibration. Fig. 3(A) is an enlarged plan view of the actuator 106. Fig. 3(B) is a cross sectional view taken along the line B-B of the actuator 106. Fig. 3(C) is a cross sectional view taken along the line C-C of the actuator 106.

[0040]

The actuator 106 has: a substrate 178 having a circular opening 161 at a substantially center thereof, a vibrating plate 176 arranged on one side (hereinafter referred to as the surface) of the substrate 178 so as to cover the opening 161, a piezoelectric layer 160 arranged on the surface side of the vibrating plate 176, an upper electrode 164 and a lower electrode 166 sandwiching the piezoelectric layer 160 therebetween, an upper electrode terminal 168 electrically connecting with the upper electrode 164, a lower electrode

terminal 170 electrically connecting with the lower electrode 166, and an auxiliary electrode 172 that is arranged between the upper electrode 164 and the upper electrode terminal 168 and electrically connects the two with each other. Each of the piezoelectric layer 160, the upper electrode 164, and the lower electrode 166 has a circular part as an essential section. The respective circular parts of the piezoelectric layer 160, the upper electrode 164 and the lower electrode 166 form a piezoelectric element.

[0041]

The vibrating plate 176 is formed on the surface of the substrate 178 so as to cover the opening 161. A cavity 162 is formed by a portion of the vibrating plate 176 facing the opening 161 and the opening 161 on the surface of the substrate 178. The surface (hereinafter referred to as the back) of the substrate 178 on the opposite side of the piezoelectric element faces inside of the liquid container side, thus, the cavity 162 is structured so as to come in contact with the liquid. The vibrating plate 176 is attached to the substrate 178 liquid-tightly, so as to prevent a liquid leakage onto the surface side of the substrate 178 even if the liquid enters inside the cavity 162.

[0042]

The lower electrode 166 is positioned on the surface of the vibrating plate 176 on the opposite side of the liquid container, in such a manner that the center of the circular part, that is, the main part of the lower electrode 166 and the center of the opening 161 almost coincide with each other. In addition, the area of the circular part of the lower electrode 166 is set so as to be smaller than the area of the opening 161. On the other hand, on the surface side of the lower electrode 166, the piezoelectric layer 160 is formed in such a manner that the center of the circular part thereof and the center of the opening 161 almost coincide with each other. The area of the circular part of the piezoelectric layer 160 is set so as to be smaller than the area of the opening 161 and larger than the area of the circular part of the lower electrode 166.

[0043]

On the other hand, on the surface side of the piezoelectric layer 160, the upper electrode 164 is formed in such a manner that the center of the circular part thereof and the center of the opening 161 almost coincide with each other. The area of the circular

part of the upper electrode 164 is set so as to be smaller than the areas of the opening 161 and of the circular part of the piezoelectric layer 160 and larger than the area of the circular part of the lower electrode 166.

[0044]

Therefore, the main part of the piezoelectric layer 160 is structured so as to be sandwiched respectively from the surface side and the back side by the main part of the upper electrode 164 and the main part of the lower electrode 166, thus, the piezoelectric layer 160 can be effectively deformed and driven. The circular parts, that is, the main parts of the piezoelectric layer 160, the upper electrode 164 and the lower electrode 166 form the piezoelectric element of the actuator 106. As mentioned above, the piezoelectric element is in contact with the vibrating plate 176. Further, among the circular part of the upper electrode 164, the circular part of the piezoelectric layer 160, the circular part of the lower electrode 166, and the opening 161, the area of the opening 161 is the largest. Because of such a structure, a vibration area of the vibrating plate 176 that can actually vibrate is determined by the opening 161. Further, the circular part of the upper electrode 164, the circular part of the piezoelectric layer 160, and the circular part of the lower electrode 166 are smaller in the area than the opening 161, so that the vibrating plate 176 can vibrate more easily. Furthermore, among the circular part of the lower electrode 166 and the circular part of the upper electrode 164, which are electrically connected to the piezoelectric layer 160, the circular part of the lower electrode 166 is smaller. Therefore, the circular part of the lower electrode 166 determines a part of the piezoelectric layer 160 that generates a piezoelectric effect.

[0045]

The upper electrode terminal 168 is formed on the surface side of the vibrating plate 176 so as to be electrically connected to the upper electrode 164 via the auxiliary electrode 172. On the other hand, the lower electrode terminal 170 is formed on the surface side of the vibrating plate 176 so as to be electrically connected to the lower electrode 166. The upper electrode 164 is formed on the surface side of the piezoelectric layer 160, so that, in the middle of connection to the upper electrode terminal 168, the upper electrode 164 must have a level difference equal to the sum of the thickness of the piezoelectric layer 160

and the thickness of the lower electrode 166. It is difficult that only the upper electrode 164 forms this level difference and, even if it can do, the connection condition between the upper electrode 164 and the upper electrode terminal 168 becomes weak, and there is a risk of cutting. Accordingly, the auxiliary electrode 172 is used as an auxiliary member so that the upper electrode 164 and the upper electrode terminal 168 are connected. By doing this, also the piezoelectric layer 160 and also the upper electrode 164 are structured so as to be supported by the auxiliary electrode 172, desired mechanical strength can be obtained, and furthermore the upper electrode 164 and the upper electrode terminal 168 can be connected surely.

[0046]

The piezoelectric element and the vibration area of the vibrating plate 176 facing the piezoelectric element are the vibration part of the actuator 106 that can vibrate actually. Further, it is preferable that the members included in the actuator 106 are calcined and formed integrally mutually. When the actuator 106 is formed integrally, the actuator 106 can be handled easily. Furthermore, when the strength of the substrate 178 is increased, the vibration characteristic can be improved. Namely, when the strength of the substrate 178 is increased, only the vibration part of the actuator 106 vibrates and a residual portion of the actuator 106 other than the vibration part do not vibrate. Further, in order to prevent the residual part of the actuator 106 other than the vibration part from vibrating, it is effective to make the piezoelectric element of the actuator 106 thinner and smaller and to make the vibrating plate 176 thinner, in addition to increasing the strength of the substrate 178.

[0047]

As a material of the piezoelectric layer 160, it is preferable to use lead zirconate titanate (PZT), lead lanthanum zirconate titanate (PLZT), or a leadless piezoelectric film using no lead and, as a material of the substrate 178, it is preferable to use zirconia or alumina. Further, it is preferable to use the same material for the vibrating plate 176 as the material of the substrate 178. For the upper electrode 164, the lower electrode 166, the upper electrode terminal 168, and the lower electrode terminal 170, a conductive material, for example, a metal such as gold, silver, copper, platinum, aluminum, or nickel may be used.

[0048]

The actuator 106 structured as mentioned above can be applied to a container that can contain a liquid. For example, it can be mounted to an ink cartridge or an ink tank to be used in an ink jet recording apparatus or to a container for containing a cleaning liquid for cleaning a recording head.

[0049]

The actuator 106 shown in Fig. 3 is mounted at a predetermined location of the liquid container in such a manner that the cavity 162 comes in contact with a liquid contained in the liquid container. When a liquid is sufficiently contained in the liquid container, the cavity 162 and the outside thereof are full of liquid. On the other hand, when the liquid of the liquid container is consumed and the liquid level lowers below the actuator mounting location, a condition wherein a liquid remains only in the cavity 162 and air exists outside the cavity 162 is generated. The actuator 106 detects at least a difference in the acoustic impedance caused by this change in the condition. Thereby, the actuator 106 can detect whether a liquid is sufficiently contained in the liquid container or a fixed amount of liquid or more is consumed. Furthermore, the actuator 106 can detect also the kind of liquid contained in the liquid container.

[0050]

Figs. 4(A) and 4(B) are drawings for explaining a liquid-phobic material and a liquid-philic material, respectively. In the present embodiment, the liquid-philic nature means affinity with an optional liquid to be contained in the liquid container and includes hydrophilic nature, oil-philic nature, ultra-hydrophilic nature, and ultra-oil-philic nature.

[0051]

As shown in Figs. 4(A) and 4(B), the contact angles when a liquid L is in contact with materials B1 or B2 are θ1 or θ2, respectively. In Fig. 4(A), the contact angle θ1 is larger than the contact angle θ2. The reason is that, the material B1 has not been processed to be made liquid-philic so that it does not have a liquid-philic characteristic. On the other hand, as shown in Fig. 4(B), the contact angle θ2 is comparatively acute and this indicates that the material B2 has a liquid-philic characteristic with respect to the liquid L. In this embodiment, the contact angle of the liquid with the liquid-philic part

is about 30 degrees or less, and it is preferable that the contact angle is closer to 0 degrees.

[0052]

The liquid-philic part can be formed by making the material itself liquid-philic. Alternatively, even when the material itself is not liquid-philic, it can be made liquid-philic by covering the material with a liquid-philic material. A highly liquid-philic material generally has small liquid surface tension in the relationship with the concerned liquid.

[0053]

Figs. 5(A) and 5(B) are enlarged cross sectional views of a part of the side wall of the container body 1 where the actuator 106 is arranged. Fig. 5(A) is a cross sectional view showing a conventional example wherein a liquid-philic part is not provided. Fig. 5(B) is a cross sectional view showing an embodiment according to the present invention.

[0054]

The liquid-philic part in the present embodiment refers to as a part having an ink-philic characteristic with respect to an ink in the container body 1.

[0055]

In the conventional example shown in Fig. 5(A), a liquid-philic part is not provided. Therefore, if ink is locally adhered to a vibration area 176a when there is no ink around the actuator 106, an ink drop M may be stagnated. Thereby, the actuator 106 may detect existence of the ink by mistake, although there is no ink.

[0056]

On the other hand, in Fig. 5(B), the actuator 106 comprises a liquid-philic part having an ink-philic characteristic with respect to ink in the container body 1. At least the vibration area 176a in contact with the ink among a vibration plate 176 is included in the liquid-philic part. Even if the ink is adhered to the vibration area 176a when there is no ink around the actuator 106, the contact angle of the concerned ink is small, and the concerned ink only stays thinly on a surface of the vibration area 176a, and most ink flows down without staying. Therefore, detection of existence of the ink by the actuator 106 is not affected practically. Further, vaporized ink is also prevented from dew condensation in the vibration area 176a due to a temperature difference between an outside and an inside of the ink cartridge. Even in a case of dew condensation of ink, the

contact angle of ink is small, so that the ink just stays thinly on the surface of the vibration area 176a. Therefore, the actuator 106 may not detect existence of the ink by mistake although there is no ink. Further, the ink staying on the surface of the vibration area 176a included in the liquid-philic part is very thin, so that it is not shown in Fig. 5(B).

[0057]

The periphery of the vibration area 176a may be included in the liquid-philic part. For example, an inner side surface 161a of a cavity 162 may be included in the liquid-philic part. Furthermore, a back side surface 178a of a substrate 178 facing on an inner side of the container body 1 may be made ink-philic. Further, not only the actuator 106 but also the through hole 1c of the container body 1 and an inner wall 1d of the container body 1 may be made ink-liquid so that the actuator 106 and the container body 1 are included in the liquid-philic part. When the periphery of the vibration area 176a is thus made a liquid-philic part, the ink adhered thereto by mistake may not stay in the cavity 162 and the through hole 1c.

[0058]

Furthermore, if the inside of the cavity 162 or the through hole 1c is made ink-philic, when the ink cartridge is to be recharged with ink, an effect is produced that the ink is easily introduced into the cavity 162 or the through hole 1c. As a result, the ink can be easily refilled into the ink cartridge without using a particular method. Therefore, the ink cartridge can be recycled easily. Therefore, when the actuator 106 arranged in the ink cartridge mounted in the ink-jet recording apparatus detects an ink end condition, a user can easily replenish the ink cartridge with the ink.

[0059]

In the example of Fig. 5, the cavity 162 and the through hole 1c are designed so as to prevent the ink from staying in the cavity 162 or the through hole 1c after the ink surface level has passed through the actuator 106. However, the cavity 162 or the through hole 1c may be designed so as to make the ink positively remain in the cavity 162 or the through hole 1c. When the cavity 162 or the through hole 1c is made ink-philic and a capillary force acting at the cavity 162 or the through hole 1c is used, the ink can be made to remain easily in the cavity 162 or the through hole 1c.

[0060]

When the cavity 162 and the through hole 1c are designed so that the ink is made to positively remain in the cavity 162 or the through hole 1c, the following advantage can be obtained. Namely, even if the liquid container swings and the liquid surface level waves, since the ink remains in the cavity 162 or the through hole 1c, ink drops do not adhere locally to the vibration area of the actuator 106. Accordingly, malfunctions of the actuator can be prevented. Assuming a condition wherein a liquid in the liquid container remains in the cavity 162 or the through hole 1c as a threshold value of existence of the liquid. When there is no liquid around the cavity 162 and the amount of the liquid in the cavity 162 or the through hole 1c is smaller than the threshold value, the condition may be judged to be a liquid-not-existence condition, and when there is a liquid around the cavity 162 or the through hole 1c and the amount of the liquid is larger than the threshold value, the condition may be judged to be a liquid-existence condition. By thus specifying the threshold value, even when the ink in the cavity is dried and exhausted, the condition can be judged to be a liquid-not-existence condition and further, even if the ink is adhered to the cavity again due to swing or vibration of the carriage when the ink in the cavity is exhausted, since the amount of liquid does not exceed the threshold value, the condition can be judged to be a liquid-not-existence condition.

[0061]

Returning to the example of Fig. 5, all the portions in contact with the ink in the ink cartridge including the actuator 106, the container body 1 and the ink feed port 2 may be made ink-philic. In this case, all the portions in contact with the ink in the ink cartridge are liquid-philic.

[0062]

When the whole of the inside surface of the ink cartridge is made liquid-philic, the inside of the ink cartridge can be easily cleaned by a predetermined cleaning liquid of the liquid-philic nature. More in detail, after the ink cartridge is used, the inside thereof can be cleaned by a liquid of the liquid-philic nature. It is preferable that this predetermined cleaning liquid is a liquid having higher affinity to the inner wall of the ink cartridge and the actuator 106 than the ink contained in the container body 1. For example, when an

aqueous ink remains in the ink cartridge, the inside of the ink cartridge is cleaned with an oily cleaning liquid having higher affinity thereto. The kind of cleaning liquid is not limited as far as the cleaning liquid has a higher liquid-philic nature than the ink to the inner wall of the ink cartridge and the actuator 106. Since the cleaning liquid has a higher liquid-philic nature than the ink to the inner wall of the ink cartridge and the actuator 106, it becomes easily concordant with the inner wall of the ink cartridge and the actuator 106. Therefore, old ink and impurities remaining in the ink cartridge can be washed away simply. Furthermore, it is more preferable that the boiling point of a cleaning liquid is lower so that the ink cartridge can be dried easily after cleaning.

[0063]

Further, the ink itself to be recharged in the ink cartridge may be used as a predetermined cleaning liquid. In this case, the recharged ink itself has an affinity to the inner wall of the ink cartridge and the actuator 106. Therefore, the ink cartridge does not require the predetermined cleaning liquid. According to the present embodiment, the ink cartridge can be recycled without stagnating impurities in the container body 1.

[0064]

Furthermore, if the actuator 106 is made liquid-philic, when the ink is replenished in the container body 1, the ink becomes easily conformed to the actuator 106. Accordingly, the ink can be introduced easily into the cavity of the actuator 106. Therefore, when the ink cartridge including the container body 1 replenished with the ink is mounted on the ink-jet recording apparatus, the actuator 106 may not detect an ink-non-existence condition by mistake.

[0065]

On the contrary, a liquid-philic part may be formed so as to make the ink remain in the cavity 162 or the through hole 1c when the ink in the ink cartridge is consumed. For example, the vibration area 176a and the inner side surface 161a of the cavity 162 are made ink-philic, and the opening 161 is structured in such a size that a capillary force can act. In this case, the ink may be easily introduced into the cavity 162, and when the cavity 162 is filled with the ink once, the ink is held by the capillary force. Therefore, the ink in the ink cartridge is consumed and even when there is no ink around the actuator

106, the ink remains in the cavity 162. Furthermore, the through hole 1c may be designed to be in such a size that the capillary force can act so that the ink can remain not only in the cavity 162 but also in the through hole 1c.

[0066]

Furthermore, for example, in order to make the ink remain in the cavity 162, it is possible to make the inside surface of the cavity 162 ink-philic and make the substrate back surface 178a around the cavity 162 ink-phobic.

[0067]

The liquid-phobic nature means a phobic nature with respect to an optional liquid and includes the hydrophobic nature, oil-phobic nature, water repellency, oil repellency, water release nature, oil release nature, ultra-hydrophobic nature, ultra-oil-phobic nature, ultra-water repellency, ultra-oil repellency, ultra-water release nature, and ultra-oil release nature. Further, the contact angle of the liquid with the liquid-phobic part is 60 degrees or higher and preferably closer to 180 degrees.

[0068]

In addition, in order to make the ink remain in the through hole 1c, it is possible to make the inside of the cavity 162, the substrate back surface 178a and the inner wall of the through hole 1c ink-philic and to make the inner side surface 1d around the through hole 1c ink-phobic.

[0069]

When the inside of the cavity 162 or the through hole 1c is made ink-philic and the periphery of the cavity 162 or the through hole 1c is made ink-phobic, the ink surely remains in the cavity 162 or the through hole 1c. On the other hand, the ink can be prevented from adhering to the periphery of the portion where the ink is caused to remain by mistake.

[0070]

The reason why it is preferable to design so as to make a liquid in the liquid container remain in the cavity 162 is as follows. Depending on the mounting position and/or the mounting angle of the actuator to the liquid container, even if the surface level of a liquid in the liquid container is lower than the mounting position of the

actuator, the liquid may be adhered to the vibration area of the actuator. If the actuator detects existence of the liquid only by existence of the liquid in the vibration area, the liquid adhered to the vibration area of the actuator may disturb accurate detection of existence of the liquid. For example, when the liquid surface level is lower than the mounting position of the actuator, if the liquid container swings due to a reciprocating motion of the carriage, and hence the liquid waves, and liquid drops are adhered to the vibration area, the actuator may judge by mistake that there is sufficient liquid in the liquid container. Therefore, inversely, when a cavity designed so as to accurately detect existence of the liquid even if the liquid remains therein is positively installed, even if the liquid container swings and thus the liquid surface level waves, malfunctions of the actuator can be prevented. By thus making the inside of the cavity liquid-philic and positively making the liquid remain in the cavity, the actuator can be effectively prevented from malfunctions.

[0071]

Further, a condition wherein the ink is consumed that the ink surface level passes through the actuator 106 and the liquid in the liquid container remains in the cavity 162 of the actuator 106 is assumed as a threshold value with respect to existence of the liquid. Namely, when there is no liquid around the cavity 162 and the amount of the liquid in the cavity is smaller than the threshold value, the condition may be judged to be an ink-not-existence condition. When there is a liquid around the cavity 162 and the amount of the liquid is larger than the threshold value, the condition may be judged to be an ink-existence condition. For example, if the actuator 106 is mounted to a side wall of the liquid container, when the liquid surface level in the liquid container is lower than the mounting position of the actuator 106, the amount of the liquid in the cavity is smaller than the threshold value, so that the actuator 106 detects an ink-not-existence condition. When the liquid surface level in the liquid container is higher than the mounting position of the actuator 106, the amount of the liquid in the cavity is larger than the threshold value, so that the actuator 106 detects an ink-existence condition. By setting the threshold value as described above, even when the ink in the cavity is dried and exhausted, the condition can be judged to be an ink-not-existence condition. Even if the ink is adhered to

the cavity again due to swing or vibration of the carriage when the ink in the cavity is exhausted, since the amount of liquid does not exceed the threshold value, the condition can be judged to be an ink-non-existence condition.

[0072]

In addition, if the cavity 162 is made liquid-philic and the ink is caused to remain only in the cavity 162 after the ink surface level passes through the mounting level of the actuator 106, the amount of ink remaining in the cavity 162 can be used as a threshold value. If the cavity 162 and the through hole 1c are made liquid-philic and the ink is caused to remain in the cavity 162 and the through hole 1c, the amount of ink remaining in the cavity 162 and the through hole 1c can be used as a threshold value.

[0073]

Whether or not to make the ink remain in the cavity 162 and/or the through hole 1c can be properly decided depending on purpose of use and/or a mounting position or the like of the actuator 106.

[0074]

Next, a liquid-philic material will be explained. A liquid-philic material for forming a liquid-philic part is not limited. Therefore, an optional liquid-philic material can be used. As a strongly liquid-philic material, for example, a material on which a photocatalyst has been covered and then ultraviolet rays have been irradiated, an inorganic material, a material having an activated surface, a hydrophilic epoxy compound, a material containing fine silica particles, a compound having two or more functional groups selected from a carboxyl group, a phenolic hydroxyl group, and an epoxy group in a molecule thereof, and so on may be cited.

[0075]

As a material of the photocatalyst mentioned above, a titanium oxide photocatalyst may be considered. More in detail, anatase-type titania and rutile-type titania may be cited. When these materials are coated on a predetermined part and irradiated with ultraviolet rays, a liquid-philic part can be formed.

[0076]

As a material containing silica particles, a material wherein colloidal silica is

dispersed and stabilized in water or an organic solvent may be considered. For example, there is a material in that inorganic silica is added to a resin containing a hydroxyl group and/or an amino group. As a resin containing the hydroxyl group, acrylic resin, polyvinyl alcohol resin, epoxy resin, and so on may be cited. As a resin containing the amino group, amide resin and amino resin may be cited. Resins may be mixed so as to contain both of the hydroxyl group and the amino group, or may be compounded at the time of synthesis. More in detail, acrylic amide resin, methacrylic amide resin, amino acrylic resin, epoxy amide resin, and amino expoxy resin may be cited. When a hydroxyl group equivalent of resin, and/an amino group equivalent of resin, or a functional group equivalent when both the hydroxyl group equivalent and the amino group equivalent are considered as the functional group, are 3000 or less, the liquid-philic nature is particularly satisfactory.

[0077]

Furthermore, a material wherein an organic silane compound has been reacted with the aforementioned resin containing a hydroxyl group, a resin containing an amino group, or a resin containing both a hydroxyl group and an amino group may be used as a liquid-philic material.

[0078]

A method of covering a surface of a predetermined base material with a liquid-philic material is neither limited. Therefore, an optional method for covering a base material with a liquid-philic material may be used. As such a method using a liquid-philic material, for example, there are a plating process, a coating process, a depositing process, and so on. Alternatively, by using the other known optional arts, a liquid-philic material can be covered. As an example of coating process, a spin coating process wherein a liquid-philic material is dropped before or during rotation of a liquid-philic part and a coating process is executed by the rotation of the liquid-philic part, a dip coating process wherein a coating process is executed by immersing a liquid-philic part in a liquid-philic material, and a roll coating process wherein a coating process is executed by applying a liquid-philic material to a liquid-philic part by using a roll member; are available. Further, a liquid-philic material may be coated on a liquid-philic part by using a brush or the like. On the other hand, a liquid-phobic part may be formed by attaching a coating layer formed from a liquid-phobic

material on a predetermined area. As a deposition process, there are a CVD process, a plasma CVD process, a sputtering process, and a vacuum deposition process available.

[0079]

The surface roughness of a material may affect the liquid-philic nature. For example, by performing a surface roughening process for a material having a contact angle of not more than 90 degrees, the liquid-philic nature of the material can be enhanced. Further, for example, when a material is a liquid-philic material having a fractal structure, by increasing the roughness of a surface thereof, an ultra-hydrophilic surface or an ultra-lipophilic surface may be formed. Therefore, a surface roughening process may be performed to a surface of a liquid-philic material having the fractal structure, thereby form a liquid-philic part. However, if a material can be made liquid-philic by performing a surface roughening process, it is not limited to a material having the fractal structure.

[0080]

Figs. 6(A) and 6(B) are views of the portion of the liquid container 1 where the actuator 106 shown in Fig. 3 is arranged, and they show a case wherein ink drops are adhered to the actuator 106 and its periphery by mistake even though there is no ink. Fig. 6(A) is a cross sectional view showing a part of a conventional ink cartridge. Fig. 6(B) is a cross sectional view showing the portion in contact with the ink in the ink cartridge which is formed by a liquid-philic material or covered with a liquid-philic material.

[0081]

The ink cartridge shown in Fig. 6(A) has not been processed to be made liquid-philic, so that the contact angle θ1 of the ink is comparatively large. Therefore, when the ink is adhered by mistake to the area of the through hole 1c where the actuator 106 is arranged, the ink stays on the area of the through hole 1c. The contact angle θ1 is about 30 degrees to about 60 degrees.

[0082]

On the other hand, the ink cartridge shown in Fig. 6(B) is processed to be made liquid-philic, so that the contact angle θ2 of the ink is comparatively small and acute. Even if the ink is adhered to the area of the through hole 1c where the actuator 106 is

arranged, the ink becomes conformed to the liquid-philic part. However, the ink only stays thinly on a surface of the liquid-philic part and most ink flows down without staying. As a result, the ink does not stay at the area of the through hole 1c. The contact angle θ2 is about 20 degrees or lower and preferably closer to 0 degrees.

[0083]

Therefore, in the ink cartridge shown in Fig. 6(A), there is a possibility that the actuator 106 may misdetect existence of the ink although there is practically no ink. In the ink cartridge shown in Fig. 6(B), there is not a possibility that the actuator 106 misdetects existence of the ink although there is practically no ink.

[0084]

Fig.7 is a perspective view showing a module body 100 as one embodiment of a mounting structure for mounting the actuator 106. The module body 100 is mounted at a predetermined location of a container body 1 of an ink cartridge. The module body 100 is structured so as to detect at least changes in the acoustic impedance in an ink solution, thereby detect the consumption condition of the liquid in the container body 1. The module body 100 of this embodiment has a liquid container mount portion 101 for mounting the actuator 106 to the container 1. Further, a piezoelectric device mount portion 105 is provided to arrange the actuator 106 in the module body 100. The liquid container mount portion 101 has a substrate 102 having an almost rectangular surface, and a column 116 on the substrate 102, the column 116 containing the actuator 106 that can be vibrated by a driving signal. Further, when the module body 100 is mounted on the ink cartridge, the actuator 106 of the module body 100 is structured so as not to be touched from outside, thus, the actuator 106 can be protected from external touch. In addition, the edge of the column 116 on the top side is rounded, so that it can be easily fit at the time of mounting into the through hole formed in the ink cartridge.

[0085]

The following are manufacturing methods of an ink cartridge having a liquid-philic part.

[0086]

In a first embodiment, the actuator 106 shown in Fig. 3 is set in a predetermined

jig or masked in such a manner that the cavity 162 is exposed. Then, the predetermined jig with the actuator 106 set in is attached to a device for forming a liquid-philic part, and the inside of the cavity 162 is processed to be made liquid-philic. Thereafter, the actuator 106 is attached to the module body 100. Then, the module body 100 with the actuator 106 attached is mounted to the ink cartridge. The predetermined jig is formed, for example, from a resin or a metallic material in such a manner that a hole is formed in an area corresponding to the cavity 162. Further, portions other than the cavity 162 may be masked by using a thermoplastic resin. According to this embodiment, a liquid-philic part can be formed only in the actuator 106. Further, at the time of forming the liquid-philic part, only the actuator 106 is handled. Therefore, equipment for giving a liquid-philic nature can be made comparatively small. Thereby, the cost for manufacturing the same ink cartridge can be reduced.

[0087]

In a second embodiment, the actuator 106 is attached to the module body 100 shown in Fig. 3. Next, the actuator 106 is set in a predetermined jig or masked in such a manner that the cavity 162 is exposed. The predetermined jig is attached to a device for forming a liquid-philic part, and the inside of the cavity 162 or the inside of the cavity 162 and the module body 100 around the cavity 162 is processed to be made liquid-philic. Thereafter, the module body 100 is mounted to the ink cartridge. According to this embodiment, the liquid-philic process can be performed to the portion of the module body 100 around the cavity 162 of the actuator 106, simultaneously with to the inside of the cavity 162, thus, the inside of the cavity 162 and the portion of the module body 100 around it can be made liquid-philic.

[0088]

In a third embodiment, the actuator 106 is attached to the module body 100 shown in Fig. 3, and the module body 100 is mounted to the ink cartridge. Then, the ink cartridge itself is set in a predetermined jig or masked in such a manner that the cavity 162 of the actuator 106 is exposed. The predetermined jig is attached to a device for forming a liquid-philic part, and the inside of the cavity 162 or the inside of the cavity 162 and the portion of the module body 100 around the cavity 162 are made liquid-philic. According

to this embodiment, the liquid-philic process can be performed at the same time to the actuator 106, the module body 100 and/or the inside of the ink cartridge, thus, the inside of the cavity 162, the module body 100 around it, and moreover the inside of the ink cartridge can be made liquid-philic.

[0089]

In the module body 100 of this embodiment, it is also preferable that the potion in contact with the ink is made liquid-philic.

[0090]

Fig. 8 is a perspective view of an embodiment of an ink cartridge for containing a plurality of kinds of ink, as seen from a back side thereof. A container 8 is divided into three ink chambers 9, 10, and 11 by partitions. In the respective ink chambers, ink feed ports 12, 13, and 14 are formed, respectively. Actuators 15, 16, and 17 are attached to respective bottoms 8a of the respective ink chambers 9, 10, and 11, in such a manner that the actuators can transmit an elastic wave to ink contained in the respective ink chambers via the container 8. Regarding the inside of the container 8 of the ink cartridge or the actuators 15, 16, and 17 in this embodiment, it is preferable to make a portion or portions in contact with the ink liquid-philic.

[0091]

The embodiments of the present invention are explained above, however, the scope of the present invention is not limited to the range described in the embodiments aforementioned. Various changes or improvements can be applied to the embodiments aforementioned. It is obvious from the description in the claims that any configuration to which such various changes or improvements are applied is included in the scope of the present invention.

[0092]

[Advantages of the Invention]

As is cleared from the above description, according to the liquid container of the present invention, ink can be filled or refilled when the ink is brought in contact with the piezoelectric device fully at the time of manufacturing or recycling of the container body so as to improve the reliability of the liquid container.

[0093]

Further, according to the liquid container of the present invention, the existence of the liquid is not misdetected.

[0094]

Further, according to the piezoelectric device of the present invention, when a remaining amount of the ink is small, the liquid container can be easily refilled with the ink. Furthermore, the empty liquid container can be refilled with the ink for recycling.

[0095]

Furthermore, according to the piezoelectric device of the present invention, the inside of the liquid container can be easily cleaned at the time of recycling of the liquid container.

[Brief Description of the Drawings]

[Fig. 1]

A cross sectional view showing one embodiment of an ink cartridge for a single color to which the present invention applies, for example, black ink.

[Fig. 2]

A cross sectional view showing an embodiment of a main part of an ink jet recording apparatus appropriate for the ink cartridge shown in Fig. 1.

[Fig. 3]

A view showing an actuator 106 as one embodiment of a piezoelectric device.

[Fig. 4]

A view showing a materialhaving a liquid-philic characteristic and a material having a liquid-phobic characteristic with respect to a specific liquid.

[Fig. 5]

An enlarged cross sectional view showing a part of a liquid container 1 where the actuator 106 is arranged.

[Fig. 6]

A view showing the case where an ink drop adheres at the periphery of the actuator 106 by mistake although there is no ink.

[Fig. 7]

A perspective view showing a module body 100 as one embodiment of a mounting structure for mounting the actuator 106.

[Fig. 8]

A perspective view showing one embodiment of an ink cartridge for containing a plurality of kinds of ink, as seen from a back side thereof.

[Description of the Reference Numerals]

1: Container

1c: Through hole

1d: Inner wall

2: Ink feed port

4: Packing

5: Spring

6: Valve body

7: Semiconductor storage unit

9, 10, 11: Ink chambers

12, 13, 14: Ink feed ports

15, 16, 17: Actuators

30: Carriage

31: Recording head

32: Ink feed needle

33: Subtank unit

100: Module body

101: Liquid container mount portion

102: Substrate

106: Actuator

116: Column

160: Piezoelectric layer

161: Opening

162: Cavity

164: Upper electrode

166: Lower electrode

168: Upper electrode terminal

170: Lower electrode terminal

172: Auxiliary electrode

176: Vibrating plate

176a: Vibrating area

178: Substrate

187a: Backside surface of substrate

L: Liquid

B1, B2: Materials

θ: Contact angle

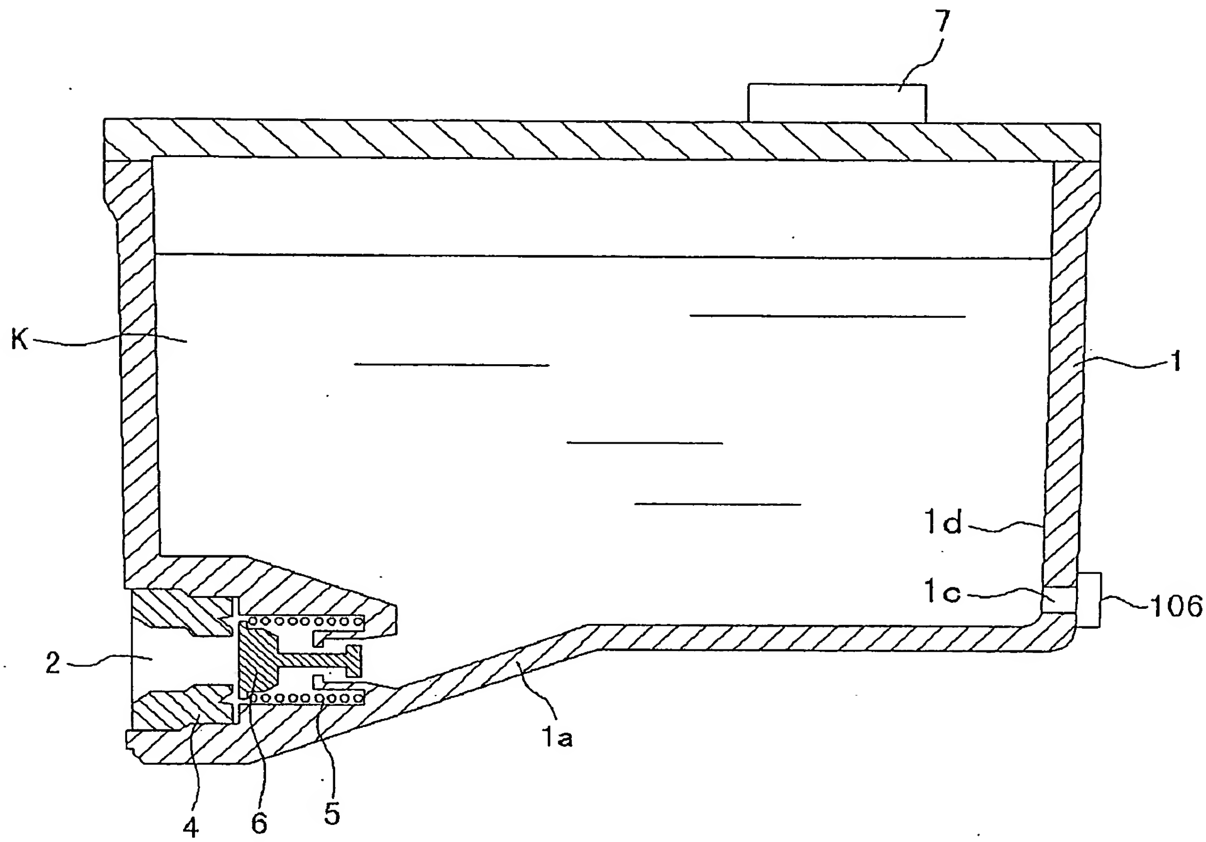


Fig. 1

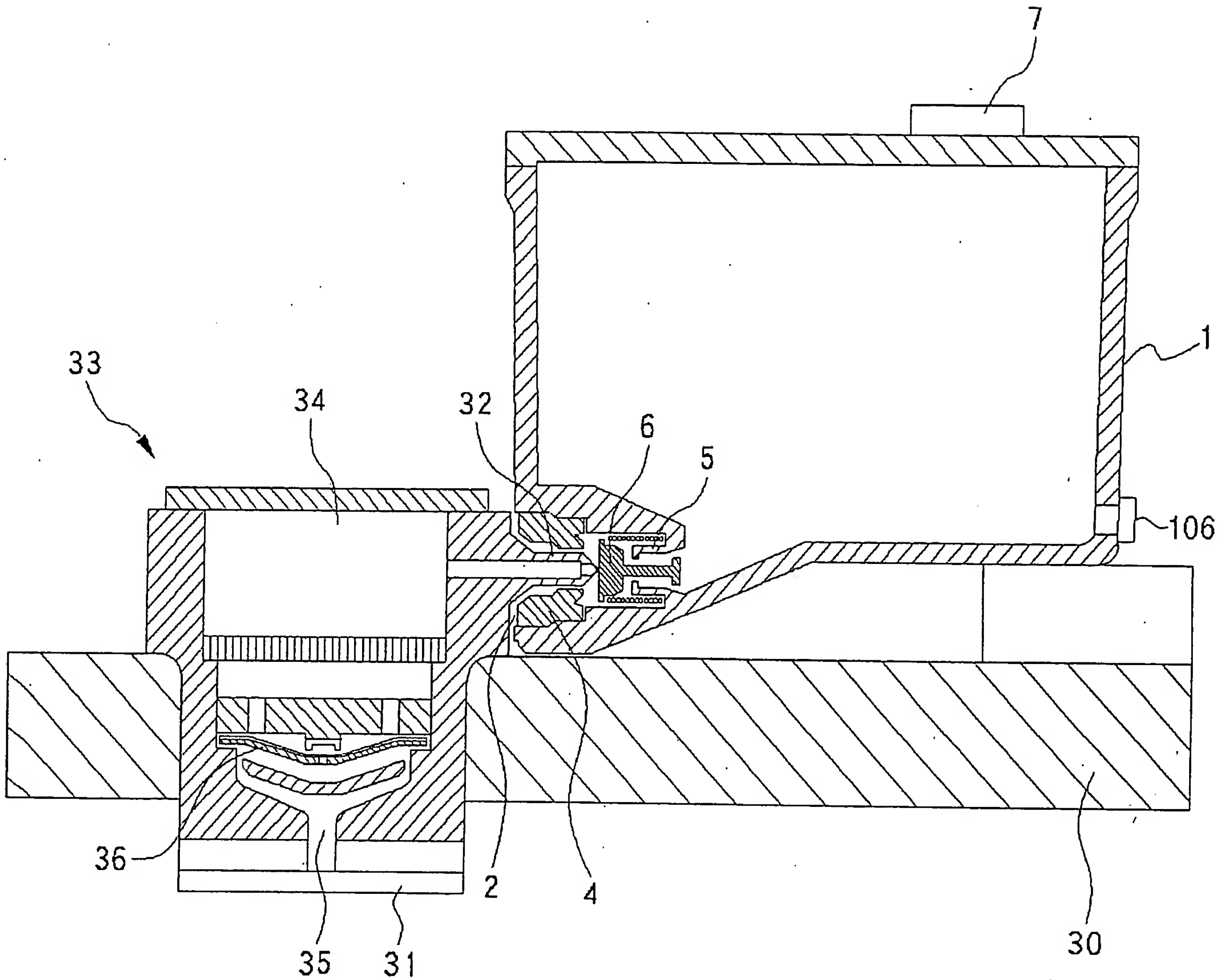
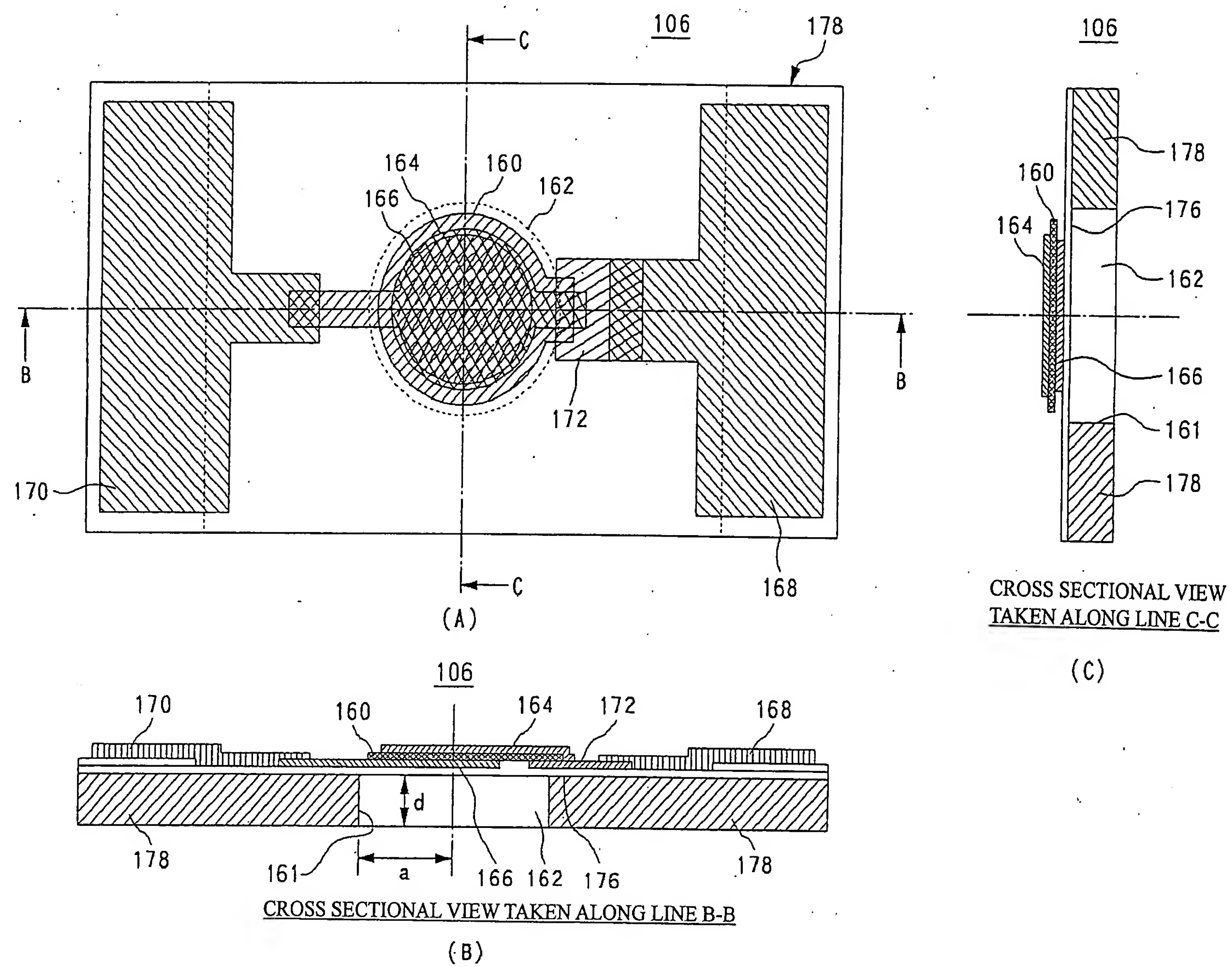


Fig. 2


106
178
164
160
162
166
172
170
168
B
C
(A)
106
160
164
178
176
162
166
161
CROSS SECTIONAL VIEW TAKEN ALONG LINE C-C
(C)
106
170
160
164
172
168
d
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161
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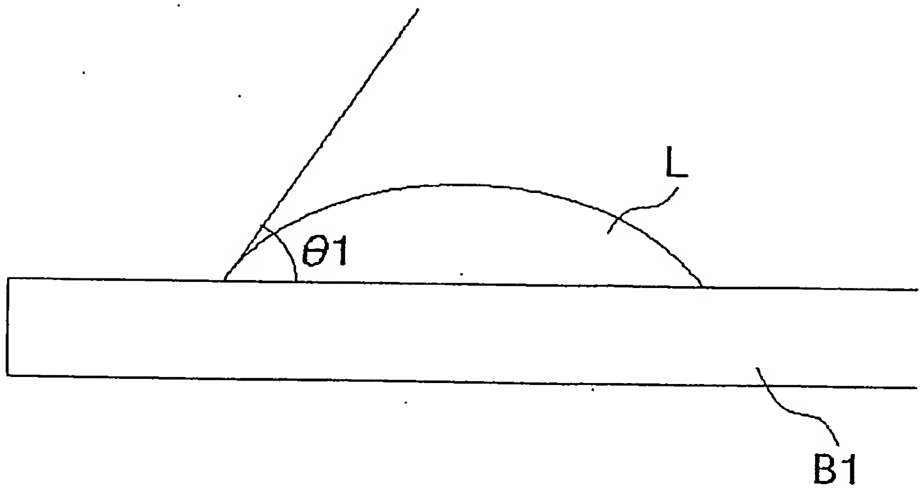
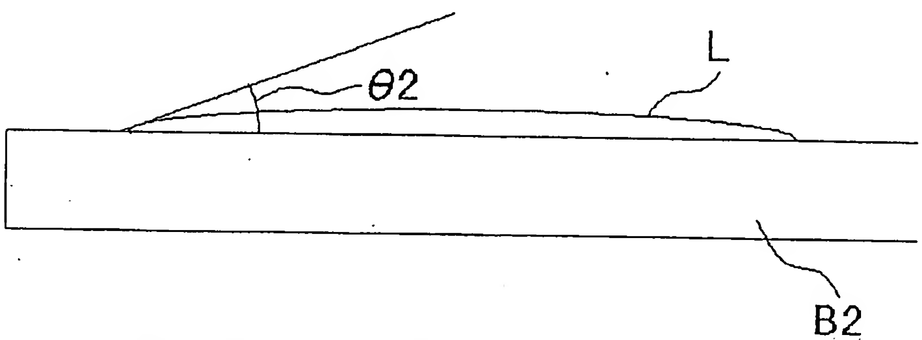
166
162
176
CROSS SECTIONAL VIEW TAKEN ALONG LINE B-B
(B)

Fig. 3



UNPROCESSED OR CONVENTIONAL MATERIAL

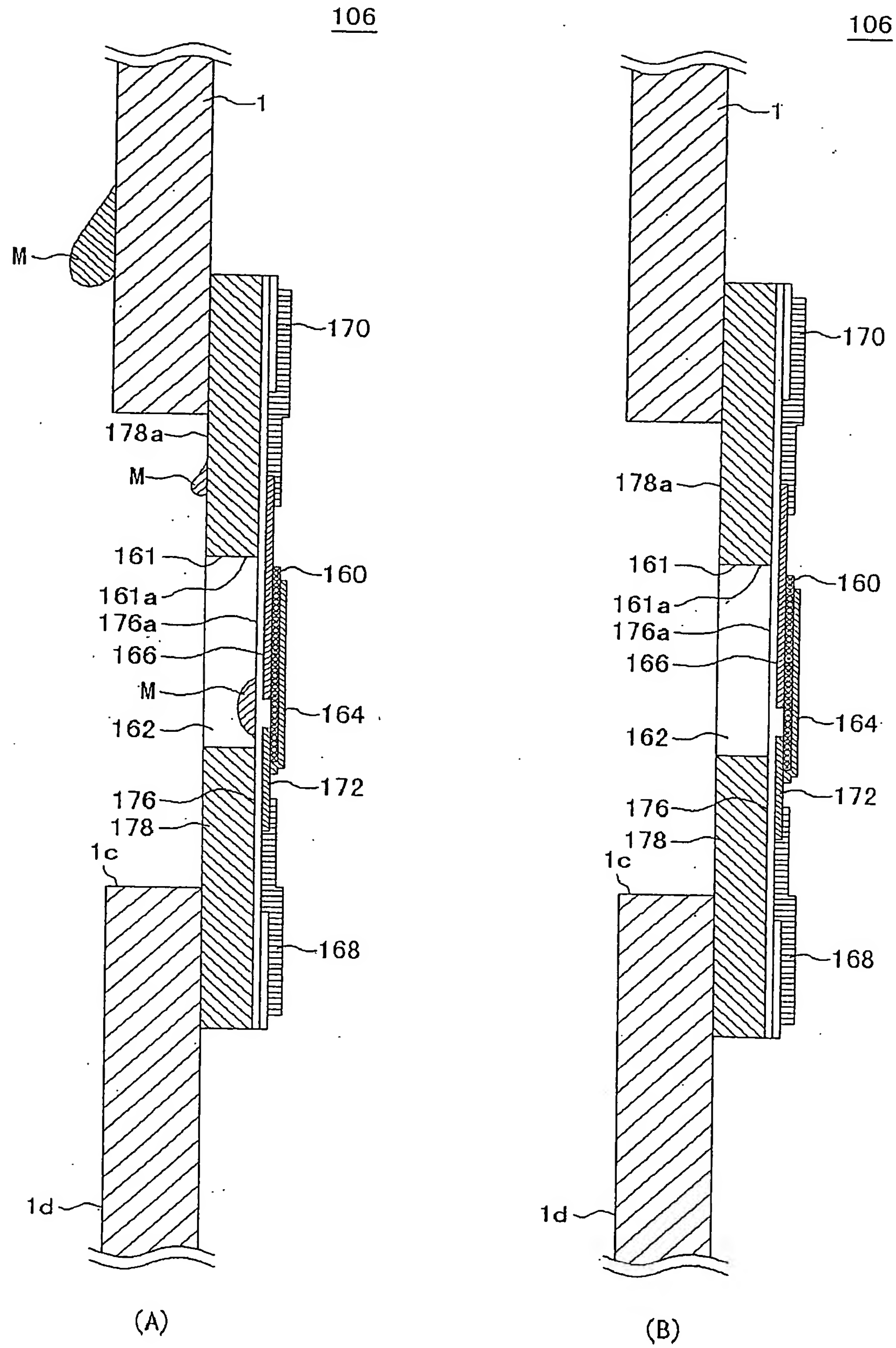
(A)



MATERIAL PROCESSED TO BE MADE
LIQUID-PHOBIC OR LIQUID-PHOBIC MATERIAL

(B)

Fig. 4



106
1
M
170
178a
M
161
160
161a
176a
166
M
164
162
172
176
178
1c
168
1d
(A)
106
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170
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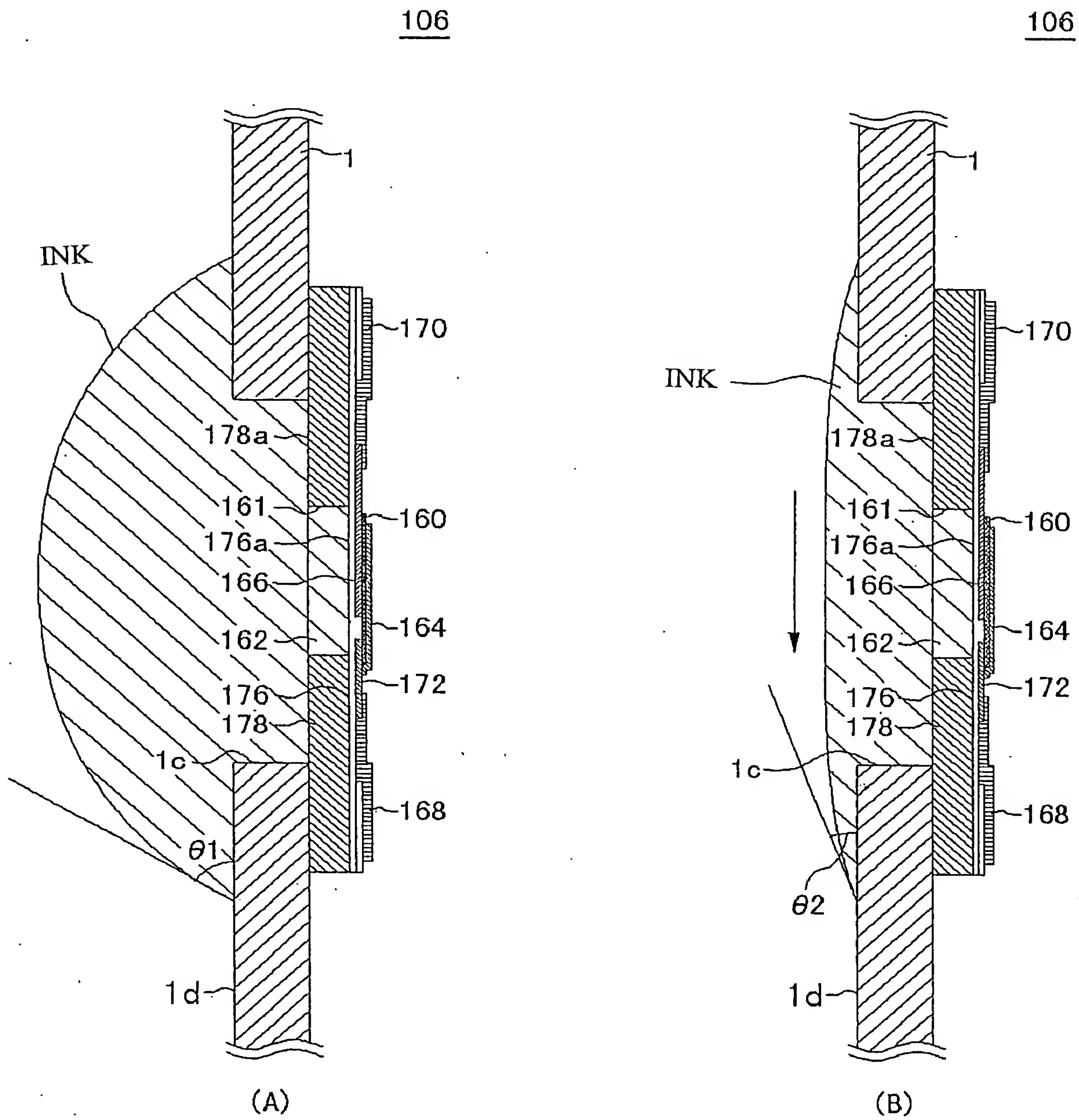
168
1d
(B)

Fig. 5


106
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INK
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178a
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1c
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θ1
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106
1
170
INK
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176a
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164
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176
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178
1c
168
θ2
1d
(B)

Fig. 6

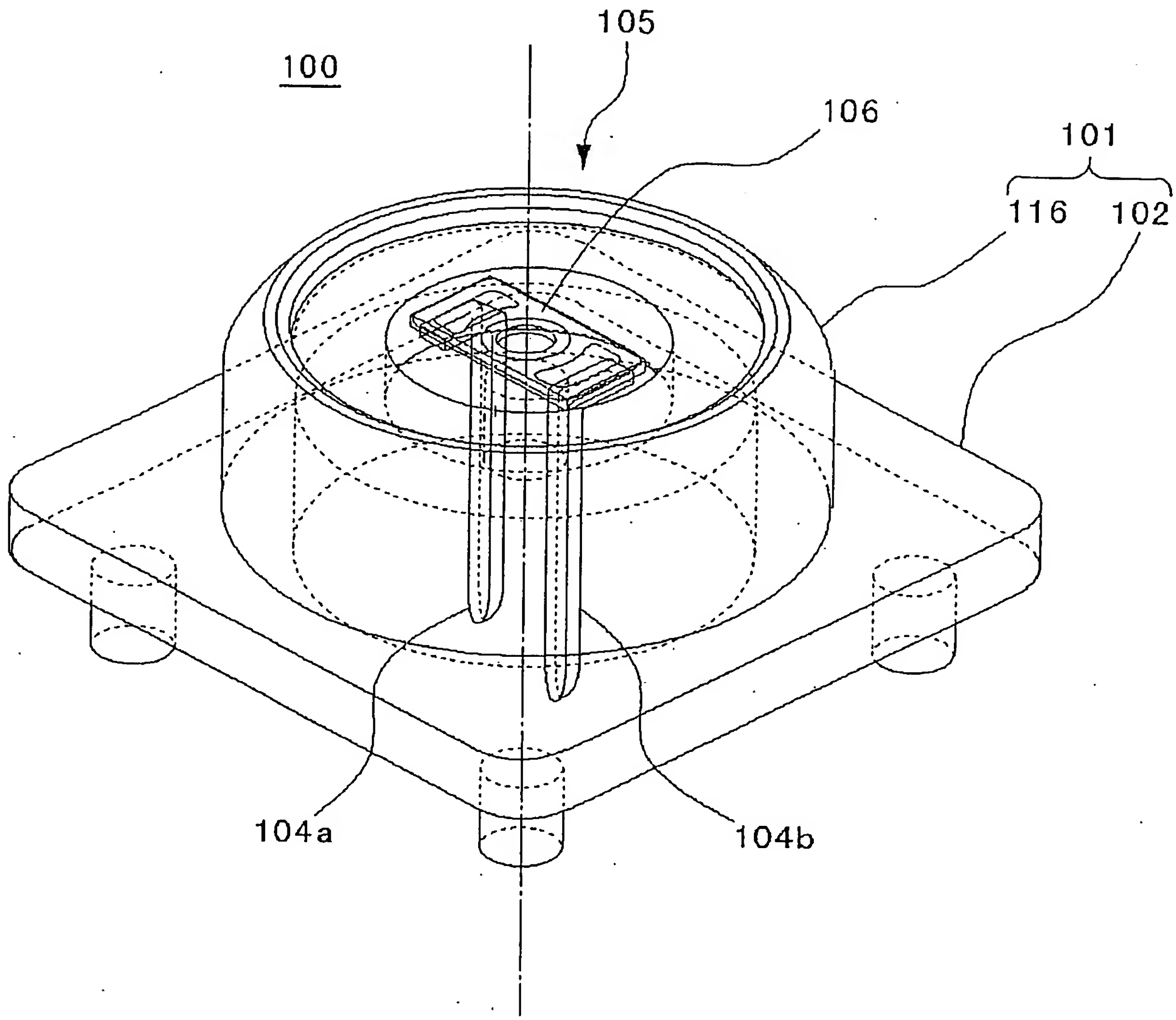

Fig. 7

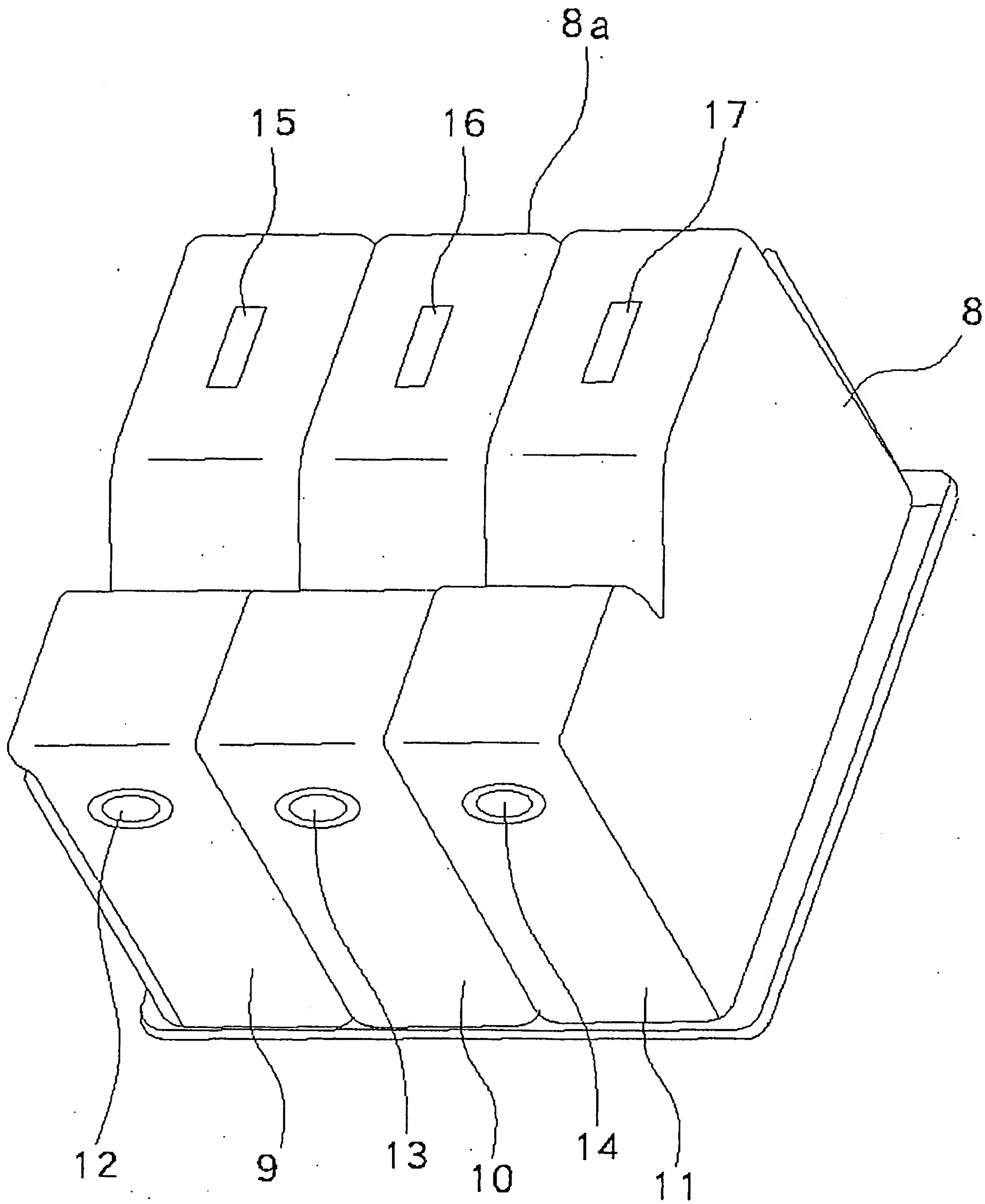

Fig. 8

[Document Type] ABSTRACT

[Abstract]

[Object]

To provide a liquid container wherein a piezoelectric device does not misdetect whether a liquid exist or not. Another object is to provide a liquid container that can be refilled when a remaining amount of liquid is small. Still another object is to provide a liquid container capable of being recycled by refilling a liquid in the empty liquid container. Still another object is to provide a liquid container of which inside can be cleaned easily at the time of recycle of the liquid container.

[Means for Solving the Problems]

A liquid container according to the present invention comprises: a container body that can be filled with a liquid; a liquid feed port that can externally supply the liquid in the container body; a piezoelectric device that can detect a consumption condition of a liquid in the container body, the piezoelectric device being provided with a liquid-philic part having a liquid-philic characteristic with respect to the liquid. The liquid container is mounted in an ink jet recording apparatus having a recording head that can jet an ink drop, and the liquid in the container is supplied to the recording head.

DECLARATION

In the matter of U.S. Patent Application Ser. No. 10/798,409 in the name of Kenji TSUKADA, et al.

I, Mariko ENDO, of Kyowa Patent and Law Office, 2-3, Marunouchi 3-Chome, Chiyoda-Ku, Tokyo-To, Japan, declare and say:

that I am thoroughly conversant with both the Japanese and English languages; and,

that the attached document represents a true English translation of Japanese Patent Application No. 2000-354802 filed on November 21, 2000.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Dated: November 29, 2005

M. Endo

Mariko ENDO

Name of Document: Patent Application

Reference Number: 12772201

Application Date: November 21, 2000

To: The Commissioner of The Patent Office

International Patent Classification: B41J 2/175

Title of the Invention: DETECTOR OF LIQUID CONSUMPTION CONDITION

Number of Claim(s): 20

Inventor:

Address: c/o Seiko Epson Corporation, 3-5, Owa 3-Chome, Suwa-Shi, Nagano-Ken
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[Title of Invention] DETECTOR OF LIQUID CONSUMPTION CONDITION

[Claims]

[Claim 1]

A detector of liquid consumption condition characterized in comprising;

a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space,

a piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and that can generate a counter electromotive force signal by a vibration of the vibrating part, and

a liquid consumption condition detecting part that can detect a liquid consumption condition based on the counter electromotive force signal from the piezoelectric device, wherein:

the containing space can contain only a predetermined volume of the liquid, and

the vibrating part is provided in a vicinity of a liquid surface in the containing space when the containing space contains the predetermined volume of the liquid.

[Claim 2]

A detector of liquid consumption condition characterized in comprising;

a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space,

a piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and that can generate a counter electromotive force signal by a vibration of the vibrating part, and

a liquid consumption condition detecting part that can detect a liquid consumption condition based on the counter electromotive force signal from the piezoelectric device, wherein:

the containing space can contain only a predetermined volume of the liquid, and

the vibrating part and the piezoelectric device are provided in a vicinity of a liquid

surface in the containing space when the containing space contains the predetermined volume of the liquid and in a vicinity of a liquid surface in the containing surface in the containing space when the liquid is exhausted from the containing surface, respectively.

[Claim 3]

A detector of liquid consumption condition characterized in comprising;

a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space,

a piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and that can generate a counter electromotive force signal by a vibration of the vibrating part, and

a liquid consumption condition detecting part that can detect a liquid consumption condition based on the counter electromotive force signal from the piezoelectric device, wherein:

the vibrating part and the piezoelectric device are provided in a vicinity of and higher and lower than a predetermined level in the containing space, respectively.

[Claim 4]

A detector of liquid consumption condition according to claim 3, characterized in that:

two pairs of the vibrating parts and the piezoelectric devices above-mentioned are formed in one module structure.

[Claim 5]

A detector of liquid consumption condition according to any one of claims 1 to 4, characterized in that:

the liquid consumption condition detecting part is adapted to measure a frequency of the counter electromotive force signal.

[Claim 6]

A detector of liquid consumption condition according to claim 5, characterized in that:

the liquid consumption condition detecting part has a counter that can count the number of vibrations in the counter electromotive force signal for a predetermined time, and

the liquid consumption condition detecting part is adapted to measure the frequency of the counter electromotive force signal, based on the number counted by the counter.

[Claim 7]

A detector of liquid consumption condition according to claim 5, characterized in that:

the liquid consumption condition detecting part has a clock-counter that can measure a time for which the counter electromotive force signal vibrates a predetermined number of times, and

the liquid consumption condition detecting part is adapted to measure the frequency of the counter electromotive force signal, based on the time measured by the clock-counter.

[Claim 8]

A detector of liquid consumption condition according to any one of claims 1 to 7, characterized in that:

the portion of the vibrating part exposed to the liquid containing space has a symmetric shape as seen from a side of the liquid containing space.

[Claim 9]

A detector of liquid consumption condition according to claim 8, characterized in that:

the piezoelectric device is fixed to a side of the vibrating part opposite to the liquid containing space at a substantially central position of the portion of the vibrating part exposed to the liquid containing space.

[Claim 10]

A detector of liquid consumption condition according to claim 8 or 9, characterized in that:

the portion of the vibrating part exposed to the liquid containing space has a circular shape as seen from the side of the liquid containing space.

[Claim 11]

A detector of liquid consumption condition according to any one of claims 1 to 10, wherein:

the piezoelectric device is adapted to vibrate in a direction substantially

perpendicular to the portion of the vibrating part exposed to the liquid containing space.

[Claim 12]

A liquid container characterized in comprising;

a wall part defining a containing space that can contain a liquid, and

a detector of liquid consumption condition according to any one of claims 1 to 11.

[Claim 13]

A liquid container according to claim 12, characterized in further comprising:

a storage that can store the liquid consumption condition detected by the liquid consumption condition detecting part.

[Claim 14]

A liquid consuming apparatus characterized in comprising;

a liquid container according to claim 12 or 13, and

a liquid consuming body that can consume the liquid contained in the liquid container, the liquid consuming body being connected to the liquid container.

[Claim 15]

A liquid consuming apparatus according to claim 14, characterized in further comprising:

a liquid replenishing unit that can replenish the containing space in the liquid container with the liquid, and

a replenishment controller that can control the liquid replenishing unit based on the liquid consumption condition of the liquid container detected by the liquid consumption condition detecting part.

[Claim 16]

A liquid consuming apparatus according to claim 14 or 15, characterized in further comprising:

a controlling circuit that can control a liquid consuming operation of the liquid consuming body, based on the liquid consumption condition of the liquid container detected by the liquid consumption condition detecting part.

[Claim 17]

A liquid consuming apparatus according to claim 14 or 15, characterized in

further comprising:

a storage that can store the liquid consumption condition detected by the liquid consumption condition detecting part, and

a controlling circuit that can control a liquid consuming operation of the liquid consuming body, based on the liquid consumption condition of the liquid container stored by the storage.

[Claim 18]

A controlling unit that can control a detector of liquid consumption condition according to any one of claims 1 to 4 characterized in that:

the controlling unit can give the driving signal to the piezoelectric device and cause the liquid consumption condition detecting part to detect the liquid consumption condition.

[Claim 19]

A storage medium capable of being read by a computer, storing a program executed by a computer system including:

at least one computer in order to materialize in the computer system a controlling unit according to claim 18.

[Claim 20]

A storage unit capable of being read by a computer, storing a program including:

a command for controlling a second program operable in a computer system including at least one computer,

the program being executed by the computer system to control the second program to materialize in the computer system a controlling unit according to claim 18.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a detector of a liquid consumption condition that can detect a consumption condition of a liquid such as an ink, by detecting changes in an acoustic impedance, particularly by detecting changes in a resonance frequency.

[0002]

[Description of the Related art]

In an ink jet recording apparatus, an ink jet recording head having: a pressure generating means that can pressurize a pressure generating chamber; and a nozzle that can jet pressurized ink as an ink drop, is mounted on a carriage.

[0003]

In the ink jet recording apparatus, ink in an ink tank continues to be fed to the recording head via a flow path, so as to permit continuous printing. The ink tank is generally structured as a removable cartridge that can be simply exchanged by a user when the ink is consumed.

[0004]

Conventionally, as an ink consumption control method of an ink cartridge, a method for totalizing the number of ink drops jetted by the recording head and the ink amount sucked at the maintenance step by means of some software and controlling the ink consumption from calculation; and a method for attaching electrodes for detecting a liquid level to the ink cartridge, detecting the point of time when the ink is actually consumed by a predetermined amount, thereby controlling the ink consumption; are known.

[0005]

The method for totalizing the number of jetted ink drops and the sucked ink amount by the software and controlling the ink consumption from calculation has an advantage in cost, because the method needs no special detector, however, in the method, some errors may be caused by difference of printing manners that can be selected by the user. In addition, larger errors may be generated when the same cartridge is refitted. Furthermore, pressure in the ink cartridge and ink viscosity may be varied with a use environment (for example, extremely high or low room temperature), or an elapsed time after opening the ink cartridge, so that unnegligible errors may be caused between the ink consumption from calculation and the actual consumption.

[0006]

On the other hand, the method of controlling the point of time of ink consumption by the electrodes can detect the actual amount of ink consumption. Therefore, it can control

the residual quantity of ink with high reliability. However, the ink has to be conductive so as to detect the ink level, accordingly the kind of ink to be detected is limited and the seal-tight structure of the electrodes is complicated. Furthermore, as a material of the electrodes, a noble metal which is enough conductive and highly corrosion-resistant is ordinarily used, so that a problem arises that manufacturing cost of an ink cartridge is increased. Furthermore, two electrodes must be mounted, so that many manufacturing steps are required and the manufacturing cost is more increased.

[0007]

[Problems to be Solved by the Invention]

In order to solve the above problems, Japanese Patent Application No. 147052/2000 discloses a piezoelectric device and a module body to be mounted on a liquid container to accurately detect an amount of liquid remaining in the liquid container without necessitating a complicated sealing structure. Further, Japanese Patent Applicatoin No. 146966/2000 discloses a detection control circuit usable for the piezoelectric device and the module body.

[0008]

The present inventors have energetically studied about mounting locations on the liquid container for the piezoelectric device and the module body to function most effectively.

[0009]

The present invention has been made under the above circumstances and an object of the present invention is to provide a detector of liquid consumption condition that can effectively make good use of the detection of the liquid consumption condition.

[0010]

[Means for Solving the Problems]

The present invention is a detector of liquid consumption condition characterized in comprising: a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space; a piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and that can generate a counter electromotive force signal by a vibration of the vibrating part; and a liquid consumption condition detecting part that can detect a

liquid consumption condition based on the counter electromotive force signal from the piezoelectric device; wherein the containing space can contain only a predetermined volume of the liquid, and the vibrating part is provided in a vicinity of a liquid surface in the containing space when the containing space contains the predetermined volume of the liquid.

[0011]

According to the present invention, so-called a “liquid-full” condition of the containing space can be detected highly reliably. The present invention is very effective for a liquid replenishment operation to fill the containing space to a “liquid-full” condition.

[0012]

Alternatively, the present invention is a detector of liquid consumption condition characterized in comprising: a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space; piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and that can generate a counter electromotive force signal by a vibration of the vibrating part; and a liquid consumption condition detecting part that can detect a liquid consumption condition based on the counter electromotive force signal from the piezoelectric device; wherein the containing space can contain only a predetermined volume of the liquid, and the vibrating part and the piezoelectric device are provided in a vicinity of a liquid surface in the containing space when the containing space contains the predetermined volume of the liquid and in a vicinity of a liquid surface in the containing surface in the containing space when the liquid is exhausted from the containing surface, respectively.

[0013]

According to the present invention, so-called a “liquid-full” condition and a “liquid-end” condition of the containing space can be detected highly reliably. The present invention is very effective for a liquid replenishment operation to fill the containing space to a “liquid-full” condition after a “liquid-end” condition has been detected.

[0014]

Alternatively, the present invention is a detector of liquid consumption condition

comprising: a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space; a piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and that can generate a counter electromotive force signal by a vibration of the vibrating part; and a liquid consumption condition detecting part that can detect a liquid consumption condition based on the counter electromotive force signal from the piezoelectric device; wherein the vibrating part and the piezoelectric device are provided in a vicinity of and higher and lower than a predetermined level in the containing space, respectively.

[0015]

According to the present invention, it can be detected highly reliably whether a liquid surface level in the containing space exists in a predetermined area defined by the two vibrating parts or not. The present invention is very effective for maintaining a liquid surface level at a substantially fixed point to maintain a liquid-head pressure at a substantially fixed point.

[0016]

For example, the liquid consumption condition detecting part may be adapted to measure a frequency of the counter electromotive force signal. The liquid consumption condition can be detected simply and precisely because the frequency of the counter electromotive force signal corresponds to the resonance frequency of the object or objects in the containing space.

[0017]

In detail, the liquid consumption condition detecting part has a counter that can count the number of vibrations in the counter electromotive force signal for a predetermined time, and the liquid consumption condition detecting part may be adapted to measure the frequency of the counter electromotive force signal based on the number counted by the counter.

[0018]

Alternatively, the liquid consumption condition detecting part has a clock-counter that can measure a time for which the counter electromotive force signal vibrates a predetermined number of times, and the liquid consumption condition detecting part

may be adapted to measure the frequency of the counter electromotive force signal based on the time measured by the clock-counter.

[0019]

In addition, preferably, the portion of the vibrating part exposed to the liquid containing space has a symmetric shape as seen from a side of the liquid containing space. Furthermore, preferably, the piezoelectric device is fixed to a side of the vibrating part opposite to the liquid containing space at a substantially central position of the portion of the vibrating part exposed to the liquid containing space.

[0020]

In particular, it is very preferable that the portion of the vibrating part exposed to the containing space has a circular shape as seen from the side of the liquid containing space.

[0021]

In addition, preferably, the piezoelectric device is adapted to vibrate in a direction substantially perpendicular to the portion of the vibrating part exposed to the liquid containing space.

[0022]

In addition, a liquid container (for example, an ink cartridge) including a detector of liquid consumption condition with the above feature and a wall part defining the containing space for containing the liquid: should be protected by the application.

[0023]

In the case, preferably, the liquid container may further comprise a storage that can store the liquid consumption condition detected by the liquid consumption condition detecting part.

[0024]

Further, a liquid consuming apparatus (for example, an ink-jet recording apparatus) including a liquid container with the above feature and a liquid consuming body that can consume the liquid contained in the liquid container, the liquid consuming body being connected to the liquid container: should be protected by the application as well.

[0025]

In the case, preferably, the liquid consuming apparatus may further comprise: a liquid replenishing unit that can replenish the containing space in the liquid container with the liquid; and a replenishment controller that can control the liquid replenishing unit based on the liquid consumption condition detected by the liquid consumption condition detecting part.

[0026]

In addition, preferably, the liquid consuming apparatus may further comprise: a controlling circuit that can control a liquid consuming operation of the liquid consuming body, based on the liquid consumption condition detected by the liquid consumption condition detecting part.

[0027]

Alternatively, preferably, the liquid consuming apparatus may further comprise: a storage that can store the liquid consumption condition detected by the liquid consumption condition detecting part; and a controlling circuit that can control a liquid consuming operation of the liquid consuming body, based on the liquid consumption condition stored by the storage.

[0028]

Furthermore, a controlling unit that can control a detector of liquid consumption condition with at least one above feature, that can give the driving signal to the piezoelectric device and that can cause the liquid consumption condition detecting part to detect the liquid consumption condition: should be protected by the application as well.

[0029]

The above controlling unit and each component thereof can be materialized by a computer system.

[0030]

Further, a program for materializing the controlling unit or each apparatus or each means thereof in the computer system, and a storage medium storing the program capable of being read by a computer, should be protected by the application as well.

[0031]

The storage medium usable herein may be not only a substantial object such as a floppy disk or the like, but also a network for transmitting various signals.

[0032]

[Description of the Preferred Embodiments]

The present invention will be explained hereunder in detail with reference to embodiments of the present invention. However, the present invention defined only by claims is not limited to the embodiments described below, and combinations of characteristics explained in the embodiments are not always necessary.

[0033]

A basic strategy of the present invention is to detect a liquid condition in a liquid container (whether a liquid exists or not, a volume of the liquid, a surface level of the liquid, a kind of the liquid, composition of the liquid, and so on) by using a vibration phenomenon.

[0034]

Some methods have been developed as concrete methods for detecting a liquid condition in a liquid container by using a vibration phenomenon. For example, there is a method of detecting a kind of medium or a change in condition of the medium in a liquid container: by generating an elastic wave toward an inside of the liquid container by means of an elastic-wave generating means; and by receiving a reflected wave that is reflected by a liquid surface or an opposite wall. Further, there is also a method of detecting a change in acoustic impedance from a vibration characteristic of a vibrating object.

[0035]

As a method of using the change in the acoustic impedance, there is a method of detecting a resonance frequency or an amplitude of a counter electromotive force waveform as the change in the acoustic impedance: by causing a vibrating part of a piezoelectric device having a piezoelectric member or an actuator to vibrate, and then by measuring the counter electromotive force generated by residual vibration remaining in the vibrating part. Alternatively, there is a method of measuring an impedance characteristic or an admittance characteristic of the liquid by means of a measuring

instrument such as an impedance analyzer, for example, a transmission circuit, and measuring a change in a current value or a voltage value, or a change in a frequency of a current value or a voltage value when a vibration is given to the liquid.

[0036]

An operating principle of a piezoelectric device or an actuator will be explained hereunder in detail. Figs. 1 to 2 show details and equivalent circuits, of an actuator 106 that is an embodiment of the piezoelectric device.

[0037]

The actuator 106 is used for a method of detecting at least changes in an acoustic impedance and detecting the consumption condition of a liquid in a liquid container. It is particularly used for a method of detecting a resonance frequency by residual vibration, thereby detecting changes in the acoustic impedance, and detecting the consumption condition of a liquid in a liquid container.

[0038]

Fig. 1(A) is an enlarged plan view of the actuator 106. Fig. 1(B) is a cross sectional view taken along the line B-B of the actuator 106. Fig. 1(C) is a cross sectional view taken along the line C-C of the actuator 106. Furthermore, Fig. 2(A) and 2(B) show equivalent circuits of the actuator 106. Fig. 2(C) and 2(D) respectively show an area including the actuator 106 and its equivalent circuit when an ink cartridge is full of ink, and Fig. 2(E) and 2(F) respectively show the area including the actuator 106 and its equivalent circuit when the ink cartridge contains no ink.

[0039]

The actuator 106 has: a substrate 178 having a circular opening 161 at a substantially center thereof, a vibrating plate 176 arranged on one side (hereinafter referred to as the surface) of the substrate 178 so as to cover the opening 161, a piezoelectric layer 160 arranged on the surface side of the vibrating plate 176, an upper electrode 164 and a lower electrode 166 sandwiching the piezoelectric layer 160 therebetween, an upper electrode terminal 168 electrically connecting with the upper electrode 164, a lower electrode terminal 170 electrically connecting with the lower electrode 166, and an auxiliary electrode 172 that is arranged between the upper electrode 164 and the upper electrode terminal

168 and electrically connects the two with each other.

[0040]

Each of the piezoelectric layer 160, the upper electrode 164, and the lower electrode 166 has a circular part as an essential section. And, the respective circular parts of the piezoelectric layer 160, the upper electrode 164 and the lower electrode 166 form a piezoelectric element.

[0041]

The vibrating plate 176 is formed on the surface of the substrate 178 so as to cover the opening 161.

[0042]

A cavity 162 is formed by a portion of the vibrating plate 176 facing the opening 161 and the opening 161 of the substrate 178. The surface (hereinafter referred to as the back) of the substrate 178 on the opposite side of the piezoelectric element faces inside of the liquid container side. Thus, the cavity 162 is structured so as to come in contact with the liquid. The vibrating plate 176 is further attached to the substrate 178 liquid-tightly, so as to prevent a liquid leakage onto the surface side of the substrate 178 even if the liquid enters inside the cavity 162.

[0043]

The lower electrode 166 is positioned on the surface of the vibrating plate 176 (on the opposite side of the liquid container), in such a manner that the center of the circular part, that is, the main part of the lower electrode 166 and the center of the opening 161 almost coincide with each other. The area of the circular part of the lower electrode 166 is further set so as to be smaller than the area of the opening 161.

[0044]

On the other hand, on the surface side of the lower electrode 166, the piezoelectric layer 160 is arranged (formed) in such a manner that the center of the circular part thereof and the center of the opening 161 almost coincide with each other. In this case, the area of the circular part of the piezoelectric layer 160 is set so as to be smaller than the area of the opening 161 and larger than the area of the circular part of the lower electrode 166.

[0045]

On the other hand, on the surface side of the piezoelectric layer 160, the upper electrode 164 is arranged (formed) in such a manner that the center of the circular part, that is, the main part thereof and the center of the opening 161 almost coincide with each other. The area of the circular part of the upper electrode 164 is set so as to be smaller than the areas of the opening 161 and of the circular part of the piezoelectric layer 160 and larger than the area of the circular part of the lower electrode 166.

[0046]

Therefore, the main part of the piezoelectric layer 160 is structured so as to be sandwiched respectively from the surface side and the back side by the main part of the upper electrode 164 and the main part of the lower electrode 166. Thus, the piezoelectric layer 160 can be effectively deformed and driven. The circular parts of each main part of the piezoelectric layer 160, the upper electrode 164 and the lower electrode 166 form the piezoelectric element of the actuator 106.

[0047]

As mentioned above, the piezoelectric element is in contact with the vibrating plate 176. Among the circular part of the upper electrode 164, the circular part of the piezoelectric layer 160, the circular part of the lower electrode 166, and the opening 161, the area of the opening 161 is the largest. Because of such a structure, a vibration area of the vibrating plate 176 that can actually vibrate is determined by the opening 161.

[0048]

Further, the circular part of the upper electrode 164, the circular part of the piezoelectric layer 160, and the circular part of the lower electrode 166 are all smaller in the area than the opening 161, so that the vibrating plate 176 can vibrate more easily.

[0049]

Furthermore, among the circular part of the lower electrode 166 and the circular part of the upper electrode 164, which are electrically connected to the piezoelectric layer 160, the circular part of the lower electrode 166 is smaller. Therefore, the circular part of the lower electrode 166 determines a part of the piezoelectric layer 160 that generates a piezoelectric effect.

[0050]

The circular parts of the piezoelectric layer 160, the upper electrode 164 and the lower electrode 166, which form the piezoelectric element, have centers that substantially coincide with the center of the opening 161. Further, the center of the circular opening 161, which determines the vibration portion of the vibrating plate 176, substantially coincides with a center of the whole actuator 106. Thus, a center of vibration of the actuator 106 almost coincides with the center of the actuator.

[0051]

In addition, since the main portion of the piezoelectric element and the vibration portion of the vibrating plate 176 have circular shapes, the vibrating part of the actuator 106 has a symmetric shape with respect to the center of the actuator 106.

[0052]

Since the vibration portion has a symmetric shape with respect to the center of the actuator 106, undesired vibration, which may be caused by asymmetry of the structure, can not be excited. Thus, the detection accuracy of the resonance frequency may be improved.

[0053]

In addition, since the vibration portion has a symmetric shape with respect to the center of the actuator 106, manufacture thereof may be so easy that dispersion in shapes of the piezoelectric elements may be small. That is, dispersion in the resonance frequencies of the piezoelectric elements may be small.

[0054]

In addition, since the vibration portion has a circular (isotropic) shape, it can be adhesively attached without affected by dispersion in fixing, thus, it can be adhesively attached to the liquid container more uniformly. That is, mounting performance of the actuator 106 to the liquid container is better.

[0055]

In addition, since the vibration portion of the vibrating plate 176 has a circular shape, a lower resonance mode such as a first resonance mode becomes predominant as a resonance mode of residual vibration of the piezoelectric layer 160. That is, a single

peak appears in resonance modes of the residual vibration. Thus, the peak can be clearly distinguished from noise, so that the resonance frequency of the residual vibration can be detected more precisely.

[0056]

In addition, if the area of the vibrating portion of the circular vibrating plate 176 is increased, an amplitude of the counter electromotive force waveform and a change rate of the resonance frequency depending on the existence of the liquid are increased, thus, the detection accuracy of the resonance frequency may be further improved.

[0057]

The actuator 106 has the two layers that are the base plate 178 whose compliance is small (difficult to be moved by the vibration) and the vibrating plate 176 whose compliance is large (easy to be moved by the vibration). Because of the two-layer structure, the actuator can be surely fixed to the liquid container by means of the base plate 178, and displacement of the vibrating plate 176 can be enlarged. Thus, amplitude of the counter electromotive force waveform and a change rate of the resonance frequency depending on the existence of the liquid are increased, so that the detection accuracy of the resonance frequency may be improved.

[0058]

In addition, since the vibrating plate 176 has a larger compliance, attenuation of the vibration is so small that the detection accuracy of the resonance frequency may be improved.

[0059]

In addition, a node of the vibration of the actuator 106 is located at an outside peripheral portion of the cavity 162, that is, near to an edge of the opening 161.

[0060]

The upper electrode terminal 168 is formed on the surface side of the vibrating plate 176 so as to be electrically connected to the upper electrode 164 via the auxiliary electrode 172. On the other hand, the lower electrode terminal 170 is formed on the surface side of the vibrating plate 176 so as to be electrically connected to the lower electrode 166. The upper electrode 164 is formed on the surface side of the piezoelectric layer 160, so that,

in the middle of connection to the upper electrode terminal 168, the upper electrode 164 must have a level difference equal to the sum of the thickness of the piezoelectric layer 160 and the thickness of the lower electrode 166. It is difficult that only the upper electrode 164 forms this level difference. Even if only the upper electrode 164 can form the level difference, the connection condition between the upper electrode 164 and the upper electrode terminal 168 becomes weak, and there is a risk of cutting. Accordingly, the auxiliary electrode 172 is used as an auxiliary member so that the upper electrode 164 and the upper electrode terminal 168 are connected. By doing this, also the piezoelectric layer 160 and also the upper electrode 164 are structured so as to be supported by the auxiliary electrode 172, desired mechanical strength can be obtained, and furthermore the upper electrode 164 and the upper electrode terminal 168 can be connected surely.

[0061]

In addition, the piezoelectric element and the vibration area of the vibrating plate 176 facing the piezoelectric element are the vibration part of the actuator 106 that can vibrate actually. Further, it is preferable that the members included in the actuator 106 are calcined and formed integrally mutually. When the actuator 106 is formed integrally, the actuator 106 can be handled easily.

[0062]

Furthermore, when the strength of the substrate 178 is increased, the vibration characteristic can be improved. Namely, when the strength of the substrate 178 is increased, only the vibration part of the actuator 106 vibrates and a residual portion of the actuator 106 other than the vibration part do not vibrate. Further, in order to prevent the residual part of the actuator 106 other than the vibration part from vibrating, it is effective to make the piezoelectric element of the actuator 106 thinner and smaller and to make the vibrating plate 176 thinner, in addition to increasing the strength of the substrate 178.

[0063]

As a material of the piezoelectric layer 160, it is preferable to use lead zirconate titanate (PZT), lead lanthanum zirconate titanate (PLZT), or a leadless piezoelectric film using no lead. As a material of the substrate 178, it is preferable to use zirconia or alumina. Further, it is preferable to use the same material for the vibrating plate 176 as

the material of the substrate 178. For the upper electrode 164, the lower electrode 166, the upper electrode terminal 168, and the lower electrode terminal 170, a conductive material, for example, a metal such as gold, silver, copper, platinum, aluminum, or nickel may be used.

[0064]

The actuator 106 structured as mentioned above can be applied to a container that can contain a liquid. For example, it can be mounted to an ink cartridge or an ink tank to be used in an ink jet recording apparatus or to a container for containing a cleaning liquid for cleaning a recording head.

[0065]

The actuator 106 shown in Figs. 1 and 2 is mounted at a predetermined location of the liquid container in such a manner that the cavity 162 comes in contact with a liquid contained in the liquid container. When a liquid is sufficiently contained in the liquid container, the cavity 162 and the outside thereof are full of liquid.

[0066]

On the other hand, when the liquid of the liquid container is consumed and the liquid level lowers below the actuator mounting location, a condition wherein no liquid exists in the cavity 162 is generated, or a condition wherein a liquid remains only in the cavity 162 and air exists outside the cavity 162 is generated.

[0067]

The actuator 106 detects at least a difference in the acoustic impedance caused by this change in the condition. Thereby, the actuator 106 can detect whether a liquid is sufficiently contained in the liquid container or a fixed amount of liquid or more is consumed. Furthermore, the actuator 106 can detect also the kind of liquid contained in the liquid container.

[0068]

Next, principle of liquid level detection by the actuator will be explained.

In order to detect changes in the acoustic impedance of a medium, an impedance characteristic or an admittance characteristic of the medium is measured. When the impedance characteristic or the admittance characteristic is measured, for example, a

transmission circuit can be used. The transmission circuit impresses a periodic voltage having a fixed amplitude to the medium, changes a frequency thereof, and measures a current flowing through the medium. Alternatively, the transmission circuit supplies a periodic current having a fixed amplitude to the medium, changes a frequency thereof, and measures a voltage impressed to the medium. Changes in the current or the voltage measured by the transmission circuit indicate changes in the acoustic impedance. Further, changes in the frequency fm at which the current or the voltage is maximized or minimized also indicates changes in the acoustic impedance.

[0069]

Separately from the method aforementioned, the actuator 106 can detect changes in the acoustic impedance of a liquid by using changes in the resonance frequency. The resonance frequency can be detected by measuring a counter electromotive force caused by the residual vibration remaining in the vibration part, for example, after the vibration part of the actuator has vibrated. In the case, for example, the above piezoelectric element can be used.

[0070]

The above piezoelectric element generates a counter electromotive force by the residual vibration remaining in the vibration part of the actuator. The magnitude of the counter electromotive force varies with the amplitude of the vibration part of the actuator. Therefore, as the amplitude of the vibration part of the actuator increases, the detection becomes easier. Further, a changing cycle of magnitude of the counter electromotive force varies with the frequency of the residual vibration remaining in the vibration part of the actuator. That is, the frequency of the vibration part of the actuator corresponds to the frequency of the counter electromotive force. Here, the resonance frequency is referred to as a frequency in a resonance state between the vibration part of the actuator and a medium in contact with the vibration part.

[0071]

In order to obtain the resonance frequency fs, a waveform obtained by measurement of the counter electromotive force when the vibration part and the medium are in a resonance state is subjected to the Fourier transformation. The vibration of the

actuator is accompanied by various deformations such as deflection and extension instead of deformation only in one direction, thus, the vibration of the actuator has various frequencies including the resonance frequency fs. Therefore, the waveform of the counter electromotive force when the piezoelectric element (vibrating part) and the medium are in a resonance state is subjected to the Fourier transformation and the most dominant frequency component is identified, thereby the resonance frequency fs is judged.

[0072]

When the admittance characteristic of a medium is maximum or when the impedance characteristic thereof is minimum, the frequency fm may be slightly different from the resonance frequency fs due to a dielectric loss of the medium or a mechanical loss thereof. However, it requires a great deal of time to derive the resonance frequency fs from the frequency fm that can be measured, so that the frequency fm is generally used instead of the resonance frequency fs. Then, when the output of the actuator 106 is inputted to the transmission circuit, the actuator 106 can detect at least the acoustic impedance.

[0073]

In addition, some experiments have proved that there is little difference between the frequency fm that can be identified by the method of measuring the impedance characteristic of the medium or the admittance characteristic thereof and the resonance frequency fs that can be identified by the method of measuring the counter electromagnetic force caused by the residual vibration in the vibration part of the actuator.

[0074]

The vibration area of the actuator 106 includes a portion of the vibrating plate 176 constituting the cavity 162 defined by the opening 161. When a liquid is sufficiently contained in the liquid container, the cavity 162 is full of liquid and the vibration area is in contact with the liquid in the liquid container. On the other hand, when no liquid is sufficiently contained in the liquid container, the vibration area is in contact with a liquid remaining in the cavity in the liquid container or in contact with gas or a vacuum instead of a liquid.

[0075]

The reason why the actuator 106 of the present invention is provided with the

cavity 162 is indicated below.

[0076]

Depending on the mounting position or a mounting angle of the actuator 106 to the liquid container, a liquid may adhere to the vibration area of the actuator, even if the liquid level in the liquid container is lower than the mounting position of the actuator. When the actuator detects existence of a liquid only by existence of a liquid in the vibration area, a liquid adhering to the vibration area of the actuator may thus disturb precise detection of existence of a liquid.

[0077]

For example, when the liquid level is lower than the mounting position of the actuator, if the liquid container rocks due to a reciprocating motion of the carriage, and thus the liquid waves, and thus the liquid adheres to the vibration area, the actuator may misjudge that the liquid is sufficiently contained in the liquid container.

[0078]

Therefore, in the actuator 106, by positively forming a cavity designed so as to precisely detect existence of a liquid even if the liquid remains at the vibration part inversely, malfunctions of the actuator can be prevented even if the liquid container rocks and the liquid level waves. When an actuator having a cavity is used like this, malfunctions can be prevented.

[0079]

Further, as shown in Fig. 2(E), a case that there is no liquid in the liquid container and a liquid remains in the cavity 162 of the actuator 106 is set as a threshold value of existence of a liquid. Namely, when there is no liquid around the cavity 162 and the liquid in the cavity is smaller than the threshold value, the actuator judges that there is no ink, and when there is a liquid around the cavity 162 and the liquid in the cavity is larger than the threshold value, the actuator judges that there is ink.

[0080]

For example, when the actuator 106 is mounted on a side wall of the liquid container, if the liquid in the liquid container is positioned lower than the mounting position of the actuator, the actuator judges that there is no ink, and if the liquid in the

liquid container is positioned higher than the mounting position of the actuator, the actuator judges that there is ink.

[0081]

When the threshold value is set like this, even when the ink in the cavity is dried and exhausted, the actuator can judge that there is no ink, and even when the ink adheres to the cavity again due to rocking of the carriage nevertheless the ink in the cavity is exhausted (since the amount of the adhering ink does not exceed the threshold value), the actuator can judge that there is no ink.

[0082]

Next, an operation and a principle for detecting the liquid condition in the liquid container from the resonance frequency between a medium and the vibration part of the actuator 106 obtained by measurement of the counter electromotive force will be explained by referring to Figs. 1 and 2.

[0083]

In the actuator 106, a voltage is applied between the upper electrode 164 and the lower electrode 166, respectively via the upper electrode terminal 168 and the lower electrode terminal 170. Thus, an electric field is generated in a portion of the piezoelectric layer 160 sandwiched between the upper electrode 164 and the lower electrode 166. The piezoelectric layer 160 is deformed by this electric field. When the piezoelectric layer 160 is deformed, the vibration area of the vibrating plate 176 is bent and vibrates. For a little while after the piezoelectric layer 160 is deformed, the bending vibration remains in the vibration part of the actuator 106.

[0084]

The residual vibration is free vibration of the vibration part of the actuator 106 and the medium. Therefore, when the voltage to be impressed to the piezoelectric layer 160 is set to a pulse waveform or a square waveform, the resonance state can be easily obtained between the vibration part after the voltage impression and the medium. The residual vibration includes vibration of the vibration part of the actuator 106, so that it also deforms the piezoelectric layer 160. Therefore, the piezoelectric layer 160 generates a counter electromotive force. The counter electromotive force is detected

via the upper electrode 164, the lower electrode 166, the upper electrode terminal 168, and the lower electrode terminal 170. A resonance frequency can be identified by the detected counter electromotive force. The liquid state in the liquid container can be detected based on the resonance frequency.

[0085]

Generally, the resonance frequency fs is expressed by the following formula:

$fs = 1/(2 \times \pi \times (M \times Cact)^{1/2})$ (Formula 1)

In this case, M indicates the sum of inertance Mact of the vibration part and additional inertance M', and Cact indicates compliance of the vibration part.

[0086]

Fig. 1(C) is a cross sectional view of the actuator 106 of this embodiment when no ink remains in the cavity 162. Figs. 2(A) and 2(B) show equivalent circuits of the vibration part of the actuator 106 and the cavity 162 when no ink remains in the cavity.

[0087]

Mact is a value obtained by dividing the product of the thickness and density of the vibration part by the area of the vibration part. In detail, it is expressed by the following formula as shown in Fig. 2(A).

$Mact = Mpzt + Melectrode1 + Melectrode2 + Mvib$ (Formula 2)

[0088]

In this case, Mpzt is a value obtained by dividing the product of the thickness and density of the piezoelectric layer 160 in the vibration part by the area of the piezoelectric layer 160. Melectrode1 is a value obtained by dividing the product of the thickness and density of the upper electrode 164 in the vibration part by the area of the upper electrode 164. Melectrode2 is a value obtained by dividing the product of the thickness and density of the lower electrode 166 in the vibration part by the area of the lower electrode 166. Mvib is a value obtained by dividing the product of the thickness and density of the vibrating plate 176 in the vibration part by the area of the vibration area of the vibrating plate 176.

[0089]

However, in order to allow Mact to be calculated from the thickness, density,

and area of the whole vibration part, it is preferable that although the respective areas of the piezoelectric layer 160, the upper electrode 164, the lower electrode 166, and the vibration area of the vibrating plate 176 have the magnitude relations aforementioned, the mutual differences between the areas are minute.

[0090]

Further, in the embodiment, in the piezoelectric layer 160, the upper electrode 164 and the lower electrode 166, it is preferable that the residual parts other than the circular parts which are the main parts thereof are so minute as to be ignored for the main parts. Therefore, in the actuator 106, Mact is the sum of inertance of each of the upper electrode 164, the lower electrode 166, the piezoelectric layer 160, and the vibration area of a vibrating plate 176. Further, the compliance Cact is compliance of a part formed by the upper electrode 164, the lower electrode 166, the piezoelectric layer 160, and the vibration area of the vibrating plate 176.

[0091]

Figs. 2(A), 2(B), 2(D), and 2(F) indicate further equivalent circuits of the vibration part of the actuator 106 and the cavity 162, however in the equivalent circuits, Cact indicates the compliance of vibration part of the actuator 106. Cpzt, Celectrode1, Celectrode2, and Cvib respectively indicate compliance of the piezoelectric layer 160, the upper electrode 164, the lower electrode 166, and the vibrating plate 176, in the vibration part. Cact is expressed by Formula 3 indicated below.

$$1/Cact = (1/Cpzt) + (1/Celectrode\ 1) + (1/Celectrode\ 2) + (1/Cvib) \qquad \text{(Formula 3)}$$

By Formulas 2 and 3, Fig. 2(A) can be indicated as Fig. 2(B).

[0092]

The compliance Cact indicates a volume of a medium that can be received by deformation when pressure is applied to a unit area of the vibration part. That is, the compliance Cact indicates deformation easiness.

[0093]

Fig. 2(C) indicates a cross sectional view of the actuator 106 when a liquid is sufficiently contained in the liquid container and the periphery of the vibration part of the actuator 106 is full of liquid. M' max shown in Fig. 2(C) indicates a maximum

value of the additional inertance (a value obtained by dividing the additional mass (mass that can affect the vibration of the vibration area) by square of the area) when a liquid is sufficiently contained in the liquid container and the periphery of the vibration part of the actuator 106 is full of liquid. M' max is indicated as follows:

$$M' \max = (\pi \times \rho /(2\times k^3))\times(2\times(2\times k\times a)^3/(3\times\pi))/(\pi\times a^2)^2 \quad \text{(Formula 4)}$$

(where a indicates a radius of the vibration part, ρ density of the medium, and k a wave-number).

[0094]

In addition, formula 4 is satisfied when the vibration area of the actuator 106 is a circle having a diameter of a. The additional inertance M' is a value indicating that the mass of the vibration part is apparently increased by a medium existing in the neighborhood of the vibration part. As is apparent from Formula 4, M' max greatly varies with the radius a of the vibration part and the density ρ of the medium.

[0095]

The wave-number k is expressed by the following:

$$k = 2 \times \pi \times fact/c \quad \text{(Formula 5)}$$

(where fact indicates a resonance frequency of the vibration part, and c indicates an acoustic speed propagating through the medium.)

[0096]

Fig. 2(D) shows an equivalent circuit of the vibration part of the actuator 106 and the cavity 162 shown in Fig. 2(C) wherein the liquid is sufficiently contained in the liquid container and the periphery of the vibration part of the actuator 106 is full of the liquid.

[0097]

Fig. 2(E) indicates a cross sectional view of the actuator 106 when the liquid in the liquid container is consumed and there is no liquid remaining around the vibration part of the actuator 106, although the liquid remains in the cavity 162 of the actuator 106.

[0098]

Formula 4 is a formula indicating maximum inertance M' max decided from the ink density ρ, when the liquid container is full of the liquid. On the other hand, when the liquid in the liquid container is consumed, and the liquid remains in the cavity 162, and

the liquid around the vibration area of the actuator 106 is replaced with air or a vacuum, the additional inertance M' can be indicated as follows (in detail, see Formula 8):

$M' = \rho \times t/S$ (Formula 6),

where t indicates a thickness of a medium relating to vibration, and S indicates the area of the vibration area of the actuator 106. When the vibration area is a circle having a radius of a, $S = \pi \times a^2$.

[0099]

Therefore, the additional inertance M' follows Formula 4 when the liquid is sufficiently contained in the liquid container and the periphery of the vibration part of the actuator 106 is full of the liquid. On the other hand, when the liquid is consumed, and the liquid remains in the cavity 162, and the liquid around the vibration area of the actuator 106 is replaced with air or a vacuum, the additional inertance M' follows the Formula 6.

[0100]

Here, as shown in Fig. 2(E), the additional inertance M' when the liquid in the liquid container is consumed and there is no liquid remaining around the vibration area of the actuator 106, although the liquid remains in the cavity 162 of the actuator 106, is indicated by M' cav for convenience, so as to distinguish it from the additional inertance M' max when the periphery of the vibration area of the actuator 106 is full of the liquid.

[0101]

Fig. 2(F) shows an equivalent circuit of the vibration part of the actuator 106 and the cavity 162 shown in Fig. 2(E) wherein the liquid in the liquid container is consumed and there is no liquid remaining around the vibration area of the actuator 106, although the liquid remains in the cavity 162 of the actuator 106.

[0102]

In this case, parameters concerning the medium condition are the medium density ρ and a medium thickness t in Formula 6. When the liquid is sufficiently contained in the liquid container, the liquid is in contact with the vibration part of the actuator 106. On the other hand, when the liquid is not sufficiently contained in the liquid container, the liquid remains in the cavity, or gas or a vacuum is in contact with the vibration part

of the actuator 106. When the liquid around the actuator 106 is consumed, the additional inertance M' var in a process of moving from M' max shown in Fig. 2(C) to M' cav shown in Fig. 2(E) is changed as the medium density ρ or the medium thickness t is changed depending on the liquid containing condition in the liquid container. Thus, the resonance frequency fs is also changed. Therefore, by identifying the resonance frequency fs, the containing condition (existence) of liquid in the liquid container can be detected.

[0103]

In this case, when t = d is set as shown in Fig. 2(E) and M' cav is expressed by using the Formula 6, by substituting the depth d of the cavity for t given in Formula 6, the following is obtained:

$M'\ cav = \rho \times d/S$ (Formula 7).

[0104]

Further, if a medium is a liquid different in the kind, since the density ρ is different depending on the difference in the composition, the additional inertance M' and the resonance frequency fs are also different. Therefore, by identifying the resonance frequency fs, the kind of liquid can be detected.

[0105]

Fig. 3(A) shows graphs indicating a relationship between an ink amount in an ink tank and a resonance frequency fs of ink and a vibration part. Here, ink will be explained as an example of a liquid. The ordinate axis indicates the resonance frequency fs, and the transverse axis indicates the ink amount. When the ink composition is fixed, as the residual amount of ink reduces, the resonance frequency fs increases.

[0106]

When the ink is sufficiently contained in the ink container and the periphery of the vibration area of the actuator 106 is full of the ink, the maximum additional inertance M' max is the value expressed by Formula 4. On the other hand, when the ink is consumed, and the ink remains in the cavity 162, and the periphery of the vibration area of the actuator 106 is not full of the ink, the additional inertance M' var is calculated from Formula 6 on the basis of the medium thickness t. Since t in Formula 6 is the thickness of the medium relating to vibration, when the thickness d (see Fig. 1(B)) of

the cavity 162 of the actuator 106 in which the ink can remain is made small, that is, the substrate 178 is made sufficient thin, the process in which the ink is gradually consumed can be also detected (see Fig. 2(C)). Here, t ink is assumed as an ink thickness relating to the vibration, and t ink-max is assumed as t ink in M' max.

[0107]

For example, the actuator 106 is arranged on a bottom of the ink cartridge almost horizontally with the ink surface level. In the case, when the ink is consumed and the ink surface level reaches the height of t ink-max or less from the actuator 106, M' var is slowly changed according to Formula 6 and the resonance frequency fs is slowly changed according to Formula 1. Therefore, as long as the ink level is within the range of t, the actuator 106 can gradually detect the ink consumption condition.

[0108]

Alternatively, the actuator 106 is arranged on a side wall of the ink cartridge almost perpendicularly to the ink surface level. In the case, when the ink is consumed and the ink surface level reaches the vibration area of the actuator 106, the additional inertance M' reduces as the ink level lowers. Thus, the resonance frequency fs slowly increases according to Formula 1. Therefore, so long as the ink level is within the range of the diameter 2a (see Fig. 2(C)) of the cavity 162, the actuator 106 can gradually detect the ink consumption condition.

[0109]

A curve X shown in Fig. 3(A) shows the relationship between the ink amount of the ink contained in the ink tank and the resonance frequency fs of the ink and the vibration part when the cavity 162 of the actuator 106 arranged on the bottom is made sufficiently shallow or when the vibration area of the actuator 106 arranged on the side wall is made sufficiently large or long. It can be seen that the ink amount in the ink tank slowly reduces and the resonance frequency fs of the ink and the vibration part gradually change.

[0110]

More in detail, a case wherein the process of slow consumption of the ink can be detected is a case wherein a liquid and a gas different in density from each other

coexist around the vibration area of the actuator 106 and are related to vibration. As the ink is consumed slowly, with the media relating to vibration around the vibration area of the actuator 106, the liquid reduces, while the gas increases.

[0111]

For example, when the actuator 106 is arranged horizontally with the ink surface level and t ink is smaller than t ink-max, the media relating to vibration of the actuator 106 include both the ink and the gas. Therefore, assuming the area of the vibration area of the actuator 106 as S, when the condition less than M' max in Formula 4 is expressed by the additional masses of the ink and the gas, the following formula is obtained.

$$M' = M'\,air + M'\,ink = \rho\,air \times t\,air/S + \rho\,ink \times t\,ink/S \qquad \text{(Formula 8,)}$$

where M' air indicates inertance of the air, and M' ink indicates inertance of the ink. ρair indicates air density, and ρ ink indicates ink density. t air indicates the thickness of air relating to vibration, and t ink indicates the thickness of ink relating to vibration.

[0112]

Among the media relating to vibration around the vibration area of the actuator 106, as the liquid reduces and the gas increases, if the actuator 106 is arranged almost horizontally with the ink level, t air increases and t ink decreases. Thereby, M' var gradually reduces and the resonance frequency gradually increases. Therefore, the ink amount remaining in the ink tank or the ink consumption amount can be detected. The reason that Formula 7 is a formula of only the liquid density is that a case that the air density is so small as to be ignored for the liquid density is supposed.

[0113]

When the actuator 106 is arranged almost perpendicularly to the ink level, among the vibration area of the actuator 106, an equivalent parallel circuit (not shown in the drawing) corresponding to a region where the medium relating to vibration of the actuator 106 is only the ink and a region where the medium relating to vibration of the actuator 106 is only the gas can be supposed. Assuming the area of the region where the medium relating to vibration of the actuator 106 is only the ink as S ink and the area of the region where the medium relating to vibration of the actuator 106 is only the gas

as S air, the following formula is obtained.

$$1/M' = 1/M'_{air} + 1/M'_{ink} = S_{air}/(\rho_{air} \times t_{air}) + S_{ink}/(\rho_{ink} \times t_{ink}) \quad \text{(Formula 9)}$$

[0114]

In addition, Formula 9 is applied when no ink is held in the cavity of the actuator 106. When ink is held in the cavity of the actuator 106, the additional inertance can be calculated as the sum of M' by Formula 9 and M' cav by Formula 7.

[0115]

The vibration of the actuator 106 is changed from the depth of t ink-max to the depth of remaining ink (d) and therefore, when the actuator 106 is arranged on the bottom in such a manner that the depth of remaining ink is slightly smaller than the depth of t ink-max, the process wherein the ink gradually reduces cannot be detected. In the case, from a vibration change of the actuator in a slight change of the ink amount from t ink-max to the residual depth d, it is detected that the ink amount is changed. Further, when the actuator is arranged on the lateral side and the diameter of the opening (cavity) is small, it is difficult to detect a vibration change of the actuator during passing of the liquid surface through the opening, that is, the ink amount in the passing process, thus, it is detected whether the liquid surface level is above or below the opening.

[0116]

For example, the curve Y shown in Fig. 3(A) shows a relationship between an ink amount in the ink tank and a resonance frequency fs of the ink and the vibration part in a case of a small circular vibration area. The situation that the resonance frequency fs of the ink and the vibration part is changed strongly by the difference of ink amount Q between before and after the ink surface level in the ink tank passes the mounting position of the actuator is indicated. From this, whether a predetermined amount of the ink remains in the ink tank or not can be detected in a binary manner.

[0117]

In the method of detecting the existence of the liquid by using the actuator 106, the existence of the ink can be detected by the vibrating plate 176 directly coming into contact with liquid, thus, its detection accuracy is higher than that by the method of calculating the ink consumption volume by means of software. In addition, in the method of detecting

the existence of the ink by using electric conductivity by means of the electrodes, the detection may be affected by the mounting positions of the electrodes to the liquid container and the kind of the ink, however, in the method of detecting the existence of the liquid by using the actuator 106, the detection may be scarcely affected by the mounting position of the actuator 106 to the liquid container and the kind of the ink.

[0118]

In addition, since both of the generation of the vibration and the detection of the existence of the liquid can be achieved by the single actuator 106, the number of sensors attached to the liquid container may be reduced, compared with a method wherein the generation of the vibration and the detection of the existence of the liquid may be achieved by different sensors. Thus, the liquid container may be manufactured at smaller cost. In addition, it is preferable that the vibration frequency of the piezoelectric layer 160 is set at an inaudible area to reduce the sound generated during the operation of the actuator 106.

[0119]

Fig. 3(B) shows an example of relationship between an ink density and a resonance frequency fs of the ink and the vibration part. Here, the ink is an example of liquid and the "ink-full" and the "ink-less" mean two relative conditions, that is, never mean only so-called an ink-full condition and an ink-end condition. As shown in Fig. 3(B), if the ink density is high, the additional inertance is so large that the resonance frequency fs is reduced. Namely, the resonance frequency fs varies depending on the kind of the ink. Therefore, if the resonance frequency fs is measured, when the ink is replenished, it can be ascertained whether an ink having different density is mixed in or not. Namely, an ink tank containing a different kind of ink can be discriminated.

[0120]

Next, the condition wherein the liquid condition can be precisely detected when the size and shape of the cavity are set so that a liquid remains in the cavity 162 of the actuator 106 even when the liquid container contains little liquid as like empty will be described in detail. If the actuator 106 can detect the liquid condition when the cavity 162 is full of liquid, it can detect the liquid condition even when the cavity 162 is not full of liquid.

[0121]

The resonance frequency fs is a function of inertance M. The inertance M is the sum of inertance Mact of the vibration part and the additional inertance M'. Here, the inertance M' is related to the liquid condition. The inertance M' is a quantity showing that the mass of the vibration part is apparently increased by a medium existing in the neighborhood of the vibration part. Namely, it means an increase in the mass of the vibration part by apparently absorbing the medium by vibration of the vibration part (inertance related to the vibration increases).

[0122]

Therefore, when M' cav is larger than M' max, all the apparently absorbed medium is a liquid remaining in the cavity 162. Therefore, it is the same condition as that when the liquid container is full of liquid. In this case, the medium relating to vibration does not become smaller than M' max, so that, even if the ink is consumed, its changes cannot be detected.

[0123]

On the other hand, when M' cav is smaller than M' max shown in Formula 4, the apparently absorbed medium is a liquid remaining in the cavity 162 and a gas or a vacuum in the liquid container. In this case, M' changes unlike the condition that the liquid container is full of liquid, so that the resonance frequency fs changes. Therefore, the actuator 106 can detect the liquid condition in the liquid container.

[0124]

Namely, when the liquid container contains no liquid and a liquid remains in the cavity 162 of the actuator 106, the condition under which the actuator 106 can precisely detect the liquid condition is that M' cav is smaller than M' max. In addition, the condition M' max > M' cav under which the actuator 106 can precisely detect the liquid condition is independent of the shape of the cavity 162.

[0125]

Here, M' cav indicates mass inertance of a liquid in almost the same volume as that of the cavity 162. Therefore, from the inequality M' max > M' cav, the condition under which the actuator 106 can precisely detect the liquid condition can be expressed

as a condition of the volume of the cavity 162. For example, assuming the radius of the opening 161 of the circular cavity 162 as a and the depth of the cavity 162 as d, the following formula is held:

$M' \max > \rho \times d/\pi a^2$ (Formula 10).

When Formula 10 is expanded, the following condition is obtained:

$a/d > 3 \times \pi/8$ (Formula 11).

Therefore, when the cavity 162 of the actuator 106 has the radius a of the opening 161 and the depth d of the cavity 162 which satisfy Formula 11, even if the liquid container contains no liquid and the liquid remains in the cavity 162, the actuator 106 can detect the liquid condition free of malfunctions.

[0126]

In addition, Formulas 10 and 11 are satisfied only when the shape of the cavity 162 is circular. When the shape of the cavity is not circular, if a corresponding formula of M' max is used and πa^2 in Formula 10 is substituted for the area thereof, the relationship of a dimension such as the width and length of the cavity with the depth thereof can be derived.

[0127]

The additional inertance M' affects the acoustic impedance characteristic, so that it may be said that the method of measuring the counter electromotive force generated in the actuator 106 by the residual vibration detects at least changes in the acoustic impedance.

[0128]

Further, according to this embodiment, the actuator 106 generates the vibration and then the counter electromotive force generated in the actuator 106 by the residual vibration is measured. However, it is not always necessary that the vibration part of the actuator 106 gives the vibration to the liquid by its own vibration by the driving voltage. Namely, even if the vibration part itself does not generate the vibration, it may vibrate together with a liquid in contact therewith within a certain region, thereby the piezoelectric layer 160 may be bent and deformed. The bent and deformation generates the counter electromotive force and transfers the counter electromotive force to the upper electrode 164 and the lower electrode 166. The liquid condition may be detected by using this

phenomenon. For example, in an ink jet recording apparatus, by using vibration of the periphery of the vibration part of the actuator generated by a reciprocating motion of a carriage by a scan of a print head during a printing operation, the condition of the ink tank or the ink condition in the ink tank may be detected.

[0129]

Figs. 4(A), 4(B) and 4(C) show a waveform of residual vibration of the actuator 106 after causing the actuator 106 to vibrate and a measuring method for the residual vibration. A vertical position of the ink surface level with respect to the mounting position level of the actuator 106 in the ink cartridge can be detected by changes in the frequency or changes in the amplitude of the residual vibration after the actuator 106 has been caused to vibrate. In Figs. 4(A) to 4(C), the ordinate axis indicates voltage of counter electromotive force generated by the residual vibration of the actuator 106, and the transverse axis indicates time. By the residual vibration of the actuator 106, as shown in Figs. 4(A) to 4(C), the waveform of an analog signal of voltage is generated. Next, the analog signal is converted to a digital value corresponding to the signal frequency. In the examples shown in Figs. 4(A) to 4(C), the time required to generate four pulses from the fourth pulse of the analog signal to the eighth pulse thereof is measured.

[0130]

More in detail, after the actuator 106 has been caused to vibrate, the number of crossing a predetermined reference voltage from the low voltage side to the high voltage side is counted. And, a digital signal being high between the 4th count and the 8th count is generated, and the time from the 4th count to the 8th count is measured by a predetermined clock pulse.

[0131]

Fig. 4(A) shows a waveform when the ink surface level is positioned above the mounting position level of the actuator 106. On the other hand, Fig. 4(B) shows a waveform when there is no ink on the mounting position level of the actuator 106. The comparison of Fig. 4(A) with Fig. 4(B) shows that the time from the 4th count to the 8th count in Fig. 4(A) is longer than that in Fig. 4(B). In other words, the time from the 4th count to the 8th count varies with the existence of ink. By making use of the

difference in time, the consumption condition of the ink can be detected.

[0132]

Starting to count from the 4th count of the analog waveform means starting the measurement after stabilization of vibration of the actuator 106. Starting from the 4th count is just an example and the time may be counted from any count. In this case, a signal from the 4th count to the 8th count is detected and the time from the 4th count to the 8th count is measured by using a predetermined clock pulse. Based on the measured time, the resonance frequency can be obtained. It is preferable that the clock pulse has a clock equal to the clock for controlling a semiconductor storage unit attached to the ink cartridge. Further, there is no need to measure the time up to the 8th count, and the time up to any count may be measured. In Fig. 4, the time from the 4th count to the 8th count is measured, however, according to circuit constitution for detecting the frequency, the time between different counts may be detected.

[0133]

For example, when the quality of the ink is stable and the peak of the amplitude varies little, in order to increase the detection speed, the time from the 4th count to the sixth count may be detected, thereby the resonance frequency may be obtained. Or, when the quality of the ink is unstable and the pulse amplitude varies greatly, in order to precisely detect the residual vibration, the time from the 4th count to the 12th count may be detected.

[0134]

Further, in another embodiment, the wave-number of the voltage waveform of counter electromotive force within a predetermined period may be counted (not shown in the drawing). Also by this method, the resonance frequency can be determined. More in detail, after generation of the vibration in the actuator 106, a digital signal being high for a predetermined period is generated and the number of crossing a predetermined standard voltage from the low voltage side to the high voltage side for the predetermined period is counted. By measuring the number of the count, the existence of the ink can be detected.

[0135]

Furthermore, the comparison of Fig. 4(A) with Fig. 4(B) shows that the amplitude of the counter electromotive force waveform is different between a case that the ink cartridge

is full of the ink and a case that the ink cartridge contains no ink. Therefore, by measuring the amplitude of the counter electromotive force waveform without obtaining the resonance frequency, the ink consumption condition in the ink cartridge may be detected.

[0136]

More in detail, for example, a standard voltage is set between the peak of the counter electromotive force waveform shown in Fig. 4(A) and the peak of the counter electromotive force waveform shown in Fig. 4(B). When the actuator 106 vibrates, a digital signal being high for a predetermined time is generated, and the counter electromotive force waveform crosses the standard voltage in the predetermined time, the actuator judges that there is no ink. When the counter electromotive force waveform does not cross the standard voltage, the actuator judges that there is ink.

[0137]

Fig. 4(C) shows an example wherein the time from the 4th count to the 8th count of the pulse waveform shown in Fig. 4(A) is measured by using a predetermined clock pulse. In the drawing, five clock pulses appear between the 4th count and the 8th count (although 100 to 200 clock pulses appear therebetween actually, the smaller number of clock pulses is supposed for a simple explanation). The clock pulse has a fixed period, thus, if the number of clock pulses is counted, time can be measured. By measuring the time from the 4th count to the 8th count, the resonance frequency can be obtained. The period of the clock pulse is preferably shorter than a period of the counter electromotive force waveform, for example, if the frequency of the counter electromotive force waveform is about 400 kHz, it is preferable that the frequency of the clock pulse is as high as 16 MHz.

[0138]

Fig. 5 shows a structure of a recording apparatus controller 2000 that can detect a consumption condition of a liquid in a liquid container 1 by an actuator 106 detecting changes in an acoustic impedance and that can control an ink-jet recording apparatus based on the detected result.

[0139]

The recording apparatus controller 2000 has: a liquid consumption condition detecting part 1200 that can give a voltage for selectively driving actuators 106A and

106C to the actuators 106A and 106C set in an ink containing part (ink containing space) IS of the liquid container 1 and that can detect the liquid consumption condition from the changes in the acoustic impedance detected by the actuators 106A and 106C; and a controlling circuit 1500 that can control the recording apparatus based on the detected result about existence of the liquid outputted from the liquid consumption condition detecting part 1200.

[0140]

As shown in Fig. 5, the two actuators 106A and 106C are set at different positions in a vertical direction, in which a liquid surface level goes down when the liquid is consumed. In the case, as shown in Fig. 6, the actuator 106A is attached in the vicinity of a liquid surface level when the ink containing part (ink containing space) IS is liquid-full, and the actuator 106C is attached in the vicinity of a liquid surface level when the liquid in the ink containing part (ink containing space) IS is liquid-end. The actuators 106A and 106C are connected to semiconductor switches SWA and SWC, respectively. For example, each of the semiconductor switches SWA and SWC may be controlled by a controlling part 1400, and when one of the switches is connected, the other of the switches may be non-connected.

[0141]

The controlling circuit 1500 further includes: the controlling part 1400 that can operate based on the detected result about existence of the liquid outputted from the liquid consumption condition detecting part 1200; and a recording-apparatus-operation controlling part 1402 that can control an operation of the recording apparatus based on an instruction from the controlling part 1400. The controlling circuit 1500 further includes: a display processing part 1404, a printing-operation controlling part 1406, an ink-replenishment processing part 1408, an ink-cartridge-exchange processing part 1410, a printing-data-storing processing part 1412 and a printing-data storing part 1414, operations of these components being controlled by the recording-apparatus-operation controlling part 1402.

[0142]

Although the recording apparatus controller 2000 may be arranged in the ink-jet

recording apparatus, a part of the recording apparatus controller 2000 may be arranged outside the ink-jet recording apparatus. For example, a function of the controlling circuit 1500 may be given by an outside unit such as a computer that is connected to the recording apparatus. In addition, a partial function of the recording apparatus controller 2000 may be stored in and supplied from a recording medium as a program. By measuring the partial function of the recording apparatus controller 2000 to a computer connected to the recording apparatus as a program stored in a recording medium, the program may be easily revised and stored again in the recording medium so as to easily achieve the latest function when the partial function of the recording apparatus controller 2000 is improved, thus, the operation of the recording apparatus can be controlled always by means of the latest function.

[0143]

In addition, the partial function of the recording apparatus controller 2000 may be sent from an information processing unit such as a server to a terminal unit such as a computer connected to the recording apparatus via an electric communication line, as a program. In the case, the latest function can be easily obtained from the server via the electric communication line and can be stored in a recording medium in the computer, thus, the recording apparatus can always achieve the latest function.

[0144]

The liquid consumption condition detecting part 1200 drives the actuators 106A and 106C and detects the existence of the liquid in the liquid container 1 based on the changes in the acoustic impedance. For example, the liquid consumption condition detecting part 1200 has: a measuring circuit 800 that can measure a counter electromotive force (for example, a voltage value) generated by each of the actuators 106A and 106C due to the residual vibration; a detecting circuit 1100 that can output a signal indicating whether the liquid exists in the liquid container 1 or not based on the counter electromotive force measured by the measuring circuit 800.

[0145]

The measuring circuit 800 has a driving-voltage generating part 850 that can generate a driving voltage for driving the actuators 106A and 106C. By means of the

driving voltage generated by the driving-voltage generating part 850, one of the actuators 106A and 106C, whose corresponding switch is connected by the controlling part 1400, is driven to vibrate. The actuator continues to vibrate after it has been caused to vibrate. Such residual vibration cause the actuator to generate a counter electromotive force. The measuring circuit 800 converts a waveform of an analogue signal of the counter electromotive force generated by the actuator to a digital signal having the same frequency as the analogue signal, and outputs the digital signal to a digital circuit 900.

[0146]

The detecting circuit 1100 includes: the digital circuit 900 that can digitally count the number of pulses in the digital signal outputted by the measuring circuit 800 for a fixed time; a liquid-existence judging part 1000 that can judge whether the liquid exists or not based on the number of pulses counted by the digital circuit 900.

[0147]

In this embodiment, as shown in Figs. 4(A) and 4(B), the digital circuit 900 outputs a digital signal being high from the 4th count to the 8th count of the counter electromotive force waveform outputted by the measuring circuit 800. In addition, as shown in Fig. 4(C), the digital circuit 900 counts the number of pulses of a predetermined clock pulse (which has a shorter period than that of the counter electromotive force waveform) while the digital signal is high from the 4th count to the 8th count. The time from the 4th count to the 8th count can be measured by counting the number of pulses of the clock pulse having the fixed period. For example, clock pulses of count five appear in the case of Fig. 4(C), thus, the time can be calculated by multiply the count five and the period of the clock pulse together.

[0148]

Here, the shown clock pulse has a low frequency for a simple explanation, however, an actually used clock pulse may have a higher frequency such as 16 MHz. The liquid-existence judging part 1000 judges whether the liquid exits in the liquid container 1 or not based on the number outputted from the digital circuit 900, and outputs the judgment result to a controlling circuit part 1500.

[0149]

In this embodiment, the plurality of actuators 106A and 106C are set at the different positions in the direction, in which the liquid surface level goes down when the liquid is consumed, thus, respective liquid consumption conditions at the mounting positions of the actuators can be detected stepwise.

[0150]

The output signals from an actuator depend on whether a liquid surface level is higher or lower than the mounting position of the actuator. For example, if the frequency or the amplitude of a detected counter electromotive force changes greatly, thereby a detected signal also changes. The liquid consumption condition detecting part 1200 can judge whether the liquid surface level goes down through each of the mounting positions of the actuators 106A and 106C or not, based on the signals detected from the actuators. The detecting process may be periodically carried out, for example at predetermined timings.

[0151]

Here, a condition wherein the liquid surface level is lower than the mounting position of the actuator is assumed to be a "liquid-not-existence" condition, and a condition wherein the liquid surface level is higher than the mounting position of the actuator is assumed to be a "liquid-existence" condition. If the liquid surface level goes down through the actuator, the detected result changes from the "liquid-existence" condition to the "liquid-not-existence" condition. In this embodiment, detecting a passage of the liquid surface level means such a change in the detected result.

[0152]

As a feature of this embodiment, the controlling part 1400 selects one actuator used for detecting the impedance, in the direction in which the liquid surface level goes down, according to progress of liquid consumption. In detail, just after the liquid container 1 is set, that is, when the liquid container 1 is full of the liquid, only the semiconductor switch SWA is connected so as to use only the actuator 106A. If the liquid is consumed and the liquid surface level goes down through the actuator 106A, the actuator 106A detects the liquid-not-existence condition. In response to this, the controlling part 1400 makes the semiconductor switch SWA unconnected and makes only

the semiconductor switch SWC connected so as to change the detecting position to the lower mounting position. If the liquid is consumed and the liquid surface level goes down through the actuator 106C, the actuator 106C detects the liquid-not-existence condition.

[0153]

If the liquid consumption condition detecting part 1200 outputs a judgment result of liquid-not-existence by the actuator 106C, the controlling part 1400 carries out a predetermined small-ink-amount dealing-with process by controlling the recording-apparatus-operation controlling part 1402. The small-ink-amount dealing-with process is a process that prohibits or restricts an operation of the recording apparatus such as an unsuitable printing, taking into consideration that the residual amount of the ink is only small. The recording-apparatus-operation controlling part 1402 controls operations of the display processing part 1404, the printing-operation controlling part 1406, the ink-replenishment processing part 1408, the ink-cartridge-exchange processing part 1410 and/or the printing-data-storing processing part 1412, based on an instruction of the controlling part 1400, in order to carry out the small-ink-amount dealing-with process.

[0154]

The display processing part 1404 indicates information corresponding to whether the liquid exists in the liquid container 1 or not, which has been detected by the actuator 106. The information is shown in a display 1416 or informed by a speaker 1418. The display 1416 may be a display panel of the recording apparatus or a screen of a computer connected to the recording apparatus. Alternatively, if the display processing part 1404 is connected to the speaker 1418 and the actuator 106 detects the liquid-not-existence condition, an alarm call may be outputted from the speaker 1418. The speaker 1418 may be a speaker in the recording apparatus or a speaker of an outside unit such as a computer connected to the recording apparatus. Further, suitably, the alarm call may be a voice signal or a composite voice that indicates an ink consumption condition may be generated by a voice composite process.

[0155]

The printing-operation controlling part 1406 controls a printing part 1420 to stop a printing operation of the recording apparatus. Due to the stop of the printing

operation, a printing operation after the ink has been exhausted can be avoided. In addition, the printing-operation controlling part 1406 may prohibit carrying out the next printing process after completing a printing process, as another example of small-ink-amount dealing-with process. Thus, it can be avoided that a printing operation is stopped in the middle of one printing process, for example a printing process for one series of sentences. In addition, as an example of prohibition of the printing process, it is also preferable that a printing operation is stopped after completing a page-changing process, in order to prevent the printing process from being stopped while printing the same page.

[0156]

The ink-replenishment processing part 1408 controls an ink replenishing unit 1422 to automatically replenish the liquid container 1 with ink. Due to such a replenishment of the ink, the printing operation can be continued.

[0157]

The ink-cartridge-exchange processing part 1410 controls a cartridge exchanging unit 1424 to automatically exchange an ink cartridge. Due to such a dealing-with process, the printing operation can be continued without making trouble for the user.

[0158]

The printing-data-storing processing part 1412 stores printing data that has been not printed yet into the printing-data storing part 1414, as a small-ink-amount dealing-with process. These printing data are printing data sent to the recording apparatus after the ink-end condition has been detected. By storing the printing data, it can be avoided that the printing data that has been not printed yet are lost.

[0159]

It is unnecessary for all the components 1404-1412 to be arranged in the recording apparatus controller 2000. In addition, it is unnecessary for all the components 1404-1412 to carry out their own small-ink-amount dealing-with processes, that is, it is sufficient that at least one small-ink-amount dealing-with process is carried out. For example, if the ink-replenishment processing part 1408 or the ink-cartridge-exchange processing part 1410 carries out the process, it is unnecessary for the printing-operation controlling part 1406 to carry out the process for stopping the printing operation.

[0160]

In addition, another structure that can carry out a small-ink-amount dealing-with process, that is, another structure that can avoid an unsuitable operation due to an ink shortage may be provided. The above small-ink-amount dealing-with process may be preferably carried out after the actuator 106C has detected the "liquid-not-existence" condition at the mounting position thereof and then a printing operation by a "predetermined reserve" has been carried out. The "predetermined reserve" may be set to a suitable value smaller than that until all the ink is consumed after the actuator 106C has detected the "liquid-not-existence" condition.

[0161]

According to this embodiment, since the detecting position is switched down, all the actuators don't operate at the same time. That is, frequency of the operation of each actuator is small. Thus, an amount of data processing in the controlling part 1400 can be restricted. Therefore, the detecting operation may not reduce throughput of the printing operation.

[0162]

In addition, the driving-voltage generating part 850 and so on are commonly provided for the plurality of actuators, thus, the structure of the circuits achieves a high efficiency in arrangement space and cost.

[0163]

In addition, according to the embodiment, a "liquid-full" condition can be detected by the actuator 106A, and a "liquid-end" condition can be detected by the actuator 106C. Thus, it is very suitable for a control wherein the liquid container 1 is replenished with the liquid to the "liquid-full" condition when the "liquid-end" condition has been detected.

[0164]

Herein, a concrete example of the ink replenishing unit 1422 will be explained with reference to Fig. 7. As shown in Fig. 7, a carriage 3001 is guided by a guide member 3002 and can be constructed so as to reciprocated by a driving means which is not shown in the drawing.

[0165]

Four ink-supplying units 3003, each of which has a liquid container 1, are mounted on an upper portion of the carriage 3001. A recording head 3004 is provided at a lower side of the carriage 3001.

[0166]

Cartridge holders 3006, each of which can contain a or more ink cartridges 3005, are arranged on both sides of a movable area of the carriage 3001. An ink replenishing unit 3007 is arranged above a non-printing area in the movable area of the carriage 3001.

[0167]

The ink replenishing unit 3007 is connected to the ink cartridges 3005 via tubes 3008. And, the ink replenishing unit 3007 can be connected to ink pouring ports 3009 of the ink-supplying units 3003 in order to introduce ink into the ports when the carriage 3001 reaches an ink replenishment area. In addition, 3010 indicates a pump unit that is an ink-pouring pressure source connected to the ink replenishing unit 3007 via a tube 3011, and 3021 indicates atmospheric open ports of the ink-supplying units 3003.

[0168]

The detailed structure of the ink-supplying unit 3003 is substantially the same as that shown in Japanese Patent Application No. 315071/1999. Thus, this reference to Japanese Patent Application No. 315071/1999 serves as the explanation. Due to the reference, this specification includes all the contents of this Japanese Patent Application.

[0169]

As seen from the explanation of the present invention, it is unnecessary to provide a float for detecting a liquid surface level, differently from the ink-supplying unit in the above Japanese Patent Application. The feature wherein the float is unnecessary can lead to advantage such as a simpler structure, and hence a reduced cost, an achievement of small-sized and lightweight structure, release from various troubles caused by malfunction of the float (improvement of operation reliability), and so on.

[0170]

In addition, the number of arranged actuators is not limited. In the case, intervals between two adjacent actuators may be unfixed. For example, it is preferable that an

interval between two actuators is smaller when the two actuators are located at lower positions as liquid surface is lowered. The modification can be applied to the following other embodiments, similarly.

[0171]

In addition, in the above embodiment, the driving circuit and so on are commonly formed for the two actuators 106A and 106C, however, the circuit may be independently formed for each actuator. In the case, for example, resonance frequencies of the two actuators 106A and 106C may be detected at the same time, so that a liquid consumption condition can be judged based on whether the two resonance frequencies are the same or not. For example, if the resonance frequencies detected from the two actuators 106A and 106C are substantially the same, the liquid consumption condition is either an ink-end condition or an ink-full condition (tank-full-of-ink condition).

[0172]

In addition, as shown in Figs. 8 and 9, if only one actuator 106A is provided, only an ink-full condition (tank-full-of-ink condition) can be detected. This manner is very suitable for a unit that replenishes the liquid container with the liquid to the "liquid-full" condition immediately if the liquid consumption condition is not the "liquid-full" condition. In this case, the semiconductor switch SWA can be omitted.

[0173]

Fig. 10 is a block diagram of the recording apparatus controller 2000 of Fig. 5 together with another liquid container 1'. As shown in Fig. 11, in this embodiment, an actuator 106A is set at a position in the vicinity of and higher than a predetermined level LL of the ink containing part IS' of the liquid container 1', and an actuator 106C is set at a position in the vicinity of and lower than a predetermined level LL of the ink containing part IS' of the liquid container 1'. Other structure is substantially the same as the embodiment shown in Fig. 5.

[0174]

This embodiment is effective for always maintaining a liquid surface level in the liquid container 1' at the vicinity of the predetermined level LL. That is, when the actuator 106C detects the "liquid-not-existence" condition, the liquid is supplied into

the liquid container 1', and when the actuator 106A detects the "liquid-existence" condition, the supply of the liquid into the liquid container 1' is stopped. Thus, the liquid surface level can be always maintained at the vicinity of the predetermined level LL. If the liquid surface level is substantially fixed, a liquid-head pressure thereof is also substantially fixed and, as a result, liquid jetting performance may be improved remarkably.

[0175]

Fig. 12 shows an embodiment wherein the recording apparatus controller 2000 shown in Fig. 5 is modified. The liquid container 1 of Fig. 12 is mounted on the carriage so as to communicate with a head part 1300, which can jet the liquid in the liquid container 1 toward a recording medium such as a recording paper to carry out a printing operation. The head part 1300 is adapted to be driven by a head driver 1440. Further, the recording apparatus of Fig. 12 has a cleaning part 1436 that can absorb the liquid from the head part 1300 to clean nozzles in the head part 1300. By a cleaning driver 1432 driving a pump 1434, the cleaning part 1436 is adapted to absorb the liquid from the head part 1300.

[0176]

A controlling circuit 1502 of a recording apparatus controller 2004 shown in Fig. 12 further includes: a liquid-jetting counter (dot counter) 1450 that can count the number of ink drops jetted from the head part 1300; a liquid-consumption-volume calculating part 1452 that can calculate an ink consumption volume based on the number of ink drops counted by the liquid-jetting counter 1450; and a cleaning controller 1442 that can control the cleaning driver 1432 based on the ink consumption condition detected by the liquid consumption condition detecting part 1210; in addition to the components that the recording apparatus controller 2000 shown in Fig. 5 has. In addition, a detecting circuit 1104 has a liquid consumption condition amending part 1010 that can amend the number of ink drops counted by the liquid-jetting counter 1450 based on the ink consumption condition detected by actuators 106A to 106C.

[0177]

Then, operations of the components newly added in Fig. 12 will be explained. The liquid-jetting counter 1450 counts the number of ink drops jetted from the head part 1300

during the printing operation, and outputs the number to the liquid-consumption-volume calculating part 1452. The liquid-consumption-volume calculating part 1452 calculates an ink volume jetted from the head part based on the number of the count by the liquid-jetting counter 1450.

[0178]

In addition, the ink is also consumed even when a driving signal not relating to the printing operation is given to the printing head to jet ink drops in vain in order to recover menisci in the nozzles of the head part 1300 from their disordered state or in order to prevent the nozzles from clogging with the ink (flushing operation). Thus, the liquid-jetting counter 1450 also counts the number of ink drops during the flushing operation, and outputs the number to the liquid-consumption-volume calculating part 1452.

[0179]

The liquid-consumption-volume calculating part 1452 calculates the ink consumption volume from the numbers of ink drops jetted from the head part 1300 during the printing operation and during the flushing operation, and outputs the calculated ink consumption volume to the liquid consumption condition amending part 1010. The ink volume calculated by the liquid-consumption-volume calculating part 1452 is shown by the display 1416 of the display processing part 1404.

[0180]

In addition, even when the head part 1300 is cleaned by the cleaning part 1436 (cleaning operation), the ink in the liquid container 1 is consumed because the ink in the head part 1300 is absorbed. Thus, the liquid-consumption-volume calculating part 1452 calculates an ink consumption volume during the cleaning operation by multiplying a time for which the cleaning driver 1432 drives the pump 1434 via the cleaning controller 1442 (for example, a time for which the pump 1434 is driven by electric power) and an ink absorbing volume per unit time of the pump 1434 together.

[0181]

Thus, the liquid-consumption-volume calculating part 1452 calculates the ink consumption volume by means of the liquid-jetting counter 1450 and the cleaning controller 1442. The liquid consumption condition amending part 1010 amends the

calculated value by the liquid-consumption-volume calculating part 1452 based on the judgment result of the liquid-existence judging part 1000.

[0182]

The reason for the two outputs from the liquid-existence judging part 1000 and the liquid-consumption-volume calculating part 1452 to be used for detecting the ink consumption condition is described in the following.

[0183]

The output of the liquid-existence judging part 1000 is information obtained by the plurality of actuators 106A to 106C actually measuring the liquid surface level. On the other hand, the output of the liquid-consumption-volume calculating part 1452 is an estimated ink consumption volume calculated from the number of ink drops counted by the liquid-jetting counter 1450 and the driving time of the pump.

[0184]

The calculated value may include an error, which may be caused by an ink pressure in the ink cartridge or an ink viscosity changing dependently on a printing manner set by the user or a use environment, for example a case wherein the room temperature is extremely high or low, or a case wherein a long time has passed since the ink cartridge was opened.

[0185]

Then, the liquid consumption condition amending part 1010 amends the ink consumption volume calculated by the liquid-consumption-volume calculating part 1452, based on the judgment result of the ink-existence outputted from the liquid-existence judging part 1000. In addition, the liquid consumption condition amending part 1010 amends parameters in formulas that the liquid-consumption-volume calculating part 1452 uses for calculating the ink consumption volume, based on the judgment result of the ink-existence outputted from the liquid-existence judging part 1000. Such an amendment of the parameters in the formulas can make the formulas fit in with the environment where the ink cartridge is used. Thus, a value obtained by the formulas may be closer to an actually used value.

[0186]

If the actuator 106C detects an "ink-not-existence" condition, the printing-operation controlling part 1406, the ink-replenishment processing part 1408, the ink-cartridge-exchange processing part 1410, the printing-data-storing processing part 1412 and the cleaning controller 1442, which are controlled by the recording-apparatus-operation controlling part 1402, carry out predetermined small-ink-amount dealing-with process.

[0187]

The printing-operation controlling part 1406 may control the head driver 1440 to stop jetting the ink from the head part 1300 or to reduce the amount of jetted ink. Thus, an printing operation after the ink has been exhausted can be avoided.

[0188]

The cleaning controller 1442 may reduce the amount of absorbed ink by prohibiting the cleaning operation of the head part 1300 by the cleaning part 1436, by reducing the number of cleaning operations or by weakening an absorption force of the pump 1434, as a small-ink-amount dealing-with process. During the cleaning operation of the head part 1300, a relatively large amount of the ink is absorbed from the head part 1300. Thus, by prohibiting the cleaning operation when the amount of residual ink is small, it can be avoided that the small amount of residual ink is absorbed from the head part 1300 for the cleaning purpose, that is, it can be avoided that the ink becomes short due to the cleaning operation. Alternatively, as mentioned above, the number of cleaning operations may be reduced or the absorption force of the pump 1434 may be weakened. The controlling part 1400 selects what kind of small-ink-amount dealing-with process the printing-operation controlling part 1406 and the cleaning controller 1442 carry out, based on the volume of the residual ink in the liquid container 1.

[0189]

Fig. 13 shows an embodiment wherein the recording apparatus controller 2004 shown in Fig. 12 is modified. In the embodiment, a semiconductor storage unit 7 is mounted on the liquid container 1, and a recording apparatus controller 2006 has an information-storage controlling circuit 1444. Other structure is substantially the same as the recording apparatus controller 2004 shown in Fig. 12. Thus, explanation of the

components not relating to the semiconductor storage unit 7 and the information-storage controlling circuit 1444 is omitted.

[0190]

The liquid container 1 of this embodiment has the semiconductor storage unit 7. The semiconductor storage unit 7 is for example a memory such as an EEPROM that is rewritable. The controlling circuit 1506 has the information-storage controlling circuit 1444.

[0191]

The liquid consumption condition detecting part 1210 controls the semiconductor switches SWA and SWC and the actuators 106A and 106C to detect a liquid consumption condition in the liquid container 1, and outputs a consumption-relating information, which relates to the detection of the liquid consumption condition by using the actuators 106A and 106C, to the controlling circuit 1506.

[0192]

The controlling part 1400 writes the consumption-relating information in the semiconductor storage unit 7 via the information-storage controlling circuit 1444. In addition, the information-storage controlling circuit 1444 reads out the consumption-relating information from the semiconductor storage unit 7, and outputs it to the controlling part 1400.

[0193]

Next, the semiconductor storage unit 7 will be explained in detail. The semiconductor storage unit 7 stores the consumption-relating information that relates to the detection of the liquid consumption condition by using the actuators 106A and 106C. The consumption-relating information includes information of a detected liquid consumption condition. The information-storage controlling circuit 1444 writes the information of the liquid consumption condition obtained by using the actuators 106A and 106C, in the semiconductor storage unit 7. Then, the consumption condition information is read out, and used in the recording apparatus controller 2006.

[0194]

Especially if the liquid container 1 is removable, it is advantageous for the semiconductor storage unit 7 to store the consumption condition information. For example,

it is assumed that the liquid container 1 is removed from the ink-jet recording apparatus when the liquid is halfway consumed. At that time, the semiconductor storage unit 7 storing the consumption condition information is always together with the liquid container 1. The liquid container 1 may be mounted on the same ink-jet recording apparatus again or another ink-jet recording apparatus. At that time, the liquid consumption condition information is read out from the semiconductor storage unit 7, and the recording apparatus controller 2006 operates based on the liquid consumption condition information. For example, even when the liquid container 1 containing no or only little liquid is mounted, the matter can be informed the user. Thus, when the liquid container 1 is removable, the consumption condition information of the liquid container 1 to that point can be used surely.

[0195]

The semiconductor storage unit 7 can further store a liquid consumption condition calculated by the liquid-consumption-volume calculating part 1452 based on the number of ink drops counted by the liquid-jetting counter 1450. The actuators 106A and 106C can surely detect passages of the liquid surface level through the mounting positions, however, it is difficult to detect an ink consumption condition before and after the passages of the liquid surface level. Thus, it is preferable to estimate the ink consumption condition before and after the passages of the liquid surface level from the liquid consumption condition calculated by the liquid-consumption-volume calculating part 1452 and to make the semiconductor storage unit 7 store the estimated value.

[0196]

In addition, the consumption-relating information includes detection characteristic information to be detected correspondingly to a liquid consumption condition. In this embodiment, as the detection characteristic information, before-consumption detection characteristic information and after-consumption detection characteristic information are stored. The before-consumption detection characteristic information means a detection characteristic before the ink consumption is started, that is, a detection characteristic at an ink-full condition. The after-consumption detection characteristic information means a detection characteristic to be detected when the ink is consumed to a predetermined detection target, in concretely, a detection characteristic when the ink

surface level goes down through the mounting position level of the actuator.

[0197]

The information-storage controlling circuit 1444 reads out the detection characteristic information from the semiconductor storage unit 7, and the liquid consumption condition detecting part 1210 detects a liquid consumption condition by using the actuators, based on the detection characteristic information. If a detection signal corresponding to the before-consumption detection characteristic is obtained, it is assumed that the ink is not consumed so much and that the volume of the residual ink is large. At least, it can be surely seen that the ink surface level is above the actuator. On the other hand, when a signal corresponding to the after-consumption detection characteristic is obtained, it is assumed that the ink is consumed so much and that the volume of the residual ink is small, that is, it can be seen that the ink surface level is below the actuator.

[0198]

One advantage of making the semiconductor storage unit 7 store the detection characteristic information will be explained.

[0199]

The detection characteristic information is decided on various factors such as a shape of the liquid container 1, a spec of the actuator, a spec of the ink and so on. Thus, when a design is modified for an improvement or the like, the detection characteristic may be changed thereby. If the liquid consumption condition detecting part 1210 always uses the same detection characteristic information, it is difficult to deal with the change in the detection characteristic. On the other hand, according to this embodiment, the detection characteristic information is stored in the semiconductor storage unit 7, and is used effectively. Thus, it is easy to deal with the change in the detection characteristic. For example, even if a liquid container 1 having a new spec is provided, the recording apparatus controller 2006 can easily use detection characteristic information of the liquid container 1.

[0200]

Even if the spec of the liquid container 1 is the same, the detection characteristic may be different due to manufacture irregularity or the like. For example, the detection

characteristic may be different dependently on a shape and/or a thickness of the liquid container 1. Thus, more preferably, detection characteristic information for each liquid container 1 is measured and stored in the semiconductor storage unit 7. In this embodiment, each liquid container 1 has a semiconductor storage unit 7, so that the semiconductor storage unit 7 can store original detection characteristic information. Thus, effect of the manufacture irregularity to the detection may be reduced, so that the detection accuracy may be improved. Thus, this embodiment has an advantage that it can deal with the difference in the detection characteristics of the respective liquid containers 1.

[0201]

Fig. 14 is a flow chart showing an operation procedure of the recording apparatus controller 2006 shown in Fig. 13.

[0202]

At first, it is judged whether an ink cartridge is mounted or not (S10). That is, it can be detected that a new ink cartridge or a halfway-used ink cartridge has been mounted. A switch (not shown) or the like, which is provided in the ink-jet recording apparatus, is used for this process.

[0203]

If the ink cartridge is mounted, consumption-relating information including detection characteristic information or the like is read out from a semiconductor storage unit 7 (S12). The display processing part 1404 of the recording apparatus controller 2006, the printing-operation controlling part 1406, the ink-replenishment processing part 1408, the ink-cartridge-exchange processing part 1410, the printing-data-storing processing part 1412 and the cleaning controlling part 1442 uses the read out consumption-relating information. For example, if it is seen from the read out consumption-relating information that the volume of the residual liquid in the liquid container 1 is small, the display 1416 may show the fact that the volume of the residual liquid is small, or the operation of the head part 1300 may be stopped.

[0204]

The liquid consumption condition detecting part 1210 detects a liquid consumption condition by using the actuators 106A to 106C, based on the read out detection

characteristic information (S14). Based on the detected liquid consumption condition, it can be judged whether the liquid exists in the liquid container 1 or not (S16). If a "liquid-not-existence" condition is detected, a liquid-not-existence dealing-with step (S18) is carried out. In the liquid-not-existence dealing-with step (S18), a step of storing the printing data by the printing-data-storing processing part 1412 (S24), a step of stopping the printing operation by the printing-operation controlling part 1406 (S26) and a step of indicating the fact being the "liquid-not-existence" condition by the display processing part 1404 (S28) are included.

[0205]

In the case, due to the step of indicating the fact being the "liquid-not-existence" condition (S28), the user can exchange the ink cartridge as described below, that is, the ink-jet recording apparatus can be replenished with the ink.

[0206]

Alternatively, as the liquid-not-existence dealing-with step (S18), the ink cartridge may be automatically exchanged by the ink-cartridge-exchange processing part 1410 (S20), or the ink may be automatically replenished by the ink-replenishment processing part 1408 (S22). In the case, the ink is automatically replenished for the ink-jet recording apparatus, so that it is unnecessary for the user to exchange the ink cartridge. In the case, the procedure goes back to the step of reading out the liquid consumption information (S12) without carrying out a step of judging a cartridge exchange (S32). In addition, when the ink-replenishment step (S22) is carried out, after the ink is replenished, the semiconductor storage unit 7 stores information about how much ink the recording apparatus is replenished with (S34).

[0207]

After the printing-data storing step (S24), the printing-operation stopping step (S26) and/or the liquid-not-existence displaying step (S28) has been carried out as the liquid-not-existence dealing-with step (S18), the detected liquid consumption condition is stored in the semiconductor storage unit 7 (S30). The user can know the fact that the ink is not in the ink cartridge, due to the liquid-not-existence displaying step (S28), thus, the user can exchange the ink cartridge according to an instruction of the liquid-not-existence

displaying step (S28). In the case (S32, Y), the procedure goes back to the step of detecting a liquid consumption condition (S14). On the other hand, if the user doesn't exchange the ink cartridge, indication for further urging the user to exchange the ink cartridge may be given by the display or the speaker, and then the process ends.

[0208]

Fig. 15 is a diagram showing a circuit structure of the measuring circuit 800. The measuring circuit 800 includes a driving-voltage generating part 850, a standard-voltage generating part 816, a high-pass filter 824, an amplifying part 860 and a comparator 836. The driving-voltage generating part 850 includes two bipolar transistors of an NPN transistor 810 and a PNP transistor 812, whose base terminals B are connected to each other and whose emitter terminals E are connected to each other. The NPN transistor 810 and the PNP transistor 812 are transistors for driving the actuators 106A and 106C. One side terminals of the actuators 106A and 106C are connected to the emitter terminals E of the NPN transistor 810 and the PNP transistor 812, which are connected to each other, via the semiconductor switches SWA and SWC, respectively, and the other side terminals of them are connected to ground GND. The other side terminals of the actuators 106A and 106C may be connected to a power source Vcc (5V).

[0209]

If a trigger signal inputted from a terminal 840 to the driving-voltage generating part 850 is switched from Low High, the bases B of the NPN transistor 810 and the PNP transistor 812, which are connected to each other, rise, and the NPN transistor 810 and the PNP transistor 812 amplify a current of the inputted trigger signal and give it to one actuator via a connected semiconductor switch. In the case shown in Fig. 15, a voltage between the emitter terminal E and a collector terminal C of the PNP transistor 812 is applied to the actuator. Thus, the actuator is rapidly charged, and hence is caused to vibrate. Then, the actuator generates a counter electromotive force due to residual vibration after caused to vibrate. The counter electromotive force generated by the residual vibration of the actuator is outputted to the amplifying part 860 via the high-pass filter 824.

[0210]

The NPN transistor 810 (the PNP transistor 812 is similar) has a PN connection

between the base terminal B and the emitter terminal E, thus, if a voltage difference between the base B and the emitter E is not greater than 0.6 V, little current flows to the emitter terminal E, if a voltage difference between the base B and the emitter E is greater than 0.6 V, a greatly amplified current flows to the emitter E. That is, each of the NPN transistor 810 and the PNP transistor 812 has an insensitive band or a bias voltage of 0.6 V, thus, in total, the NPN transistor 810 and the PNP transistor 812 has a bias voltage of about 1.2 V. If a voltage between the terminals including the counter electromotive force of the actuator is within the insensitive band, the transistors don't operate and the current doesn't flow to the emitter terminals, and the residual vibration of the actuator is not restrained by operation of the transistors. If the insensitive band is not provided, the voltage of the actuator is controlled by the transistors to be fixed, it becomes impossible to examine the counter electromotive force.

[0211]

In Fig. 15, the NPN transistor 810 and the PNP transistor 812 are used as the bipolar transistors, however, electric-field-effect transistors may be used instead of the bipolar transistors. When the electric-field-effect transistors are used, an N-type electric-field-effect transistor is arranged at a position at which the NPN transistor in Fig. 15 is arranged. A gate of the N-type electric-field-effect transistor is arranged at a position at which the base B of the NPN transistor 810 is arranged, and a source thereof is arranged at a position at which the emitter terminal E. In addition, an P-type electric-field-effect transistor is arranged at a position at which the PNP transistor 812 is arranged. A gate of the P-type electric-field-effect transistor is arranged at a position at which the base terminal B of the PNP transistor 812 is arranged, and a source thereof is arranged at a position at which the emitter terminal E of the PNP transistor 812 is arranged. In addition, the gates of the P-type electric-field-effect transistor and the N-type electric-field-effect transistor are connected with each other, and the sources of the P-type electric-field-effect transistor and the N-type electric-field-effect transistor are connected with each other. It is preferable that one side terminals of the actuators are connected to the sources of the P-type electric-field-effect transistor and the N-type electric-field-effect transistor, which are connected to each other, via the semiconductor

switches, respectively, and that the other side terminals of the actuators are connected to a power source Vcc or a ground GND.

[0212]

The high-pass filter 824 has a capacitor 826 and a resistor 828. The output of the driving-voltage generating part 850 is outputted to the amplifying part 860 via the high-pass filter 824. The high-pass filter 824 outputs a high-frequency component of the output from the actuator to the amplifying part 860 and removes a low-frequency component thereof. In addition, the high-pass filter 824 has a role of adjusting the output in such a manner that the output of the amplifying part 860 is within a range of 0 to 5 V (Vcc) with arounding the standard voltage.

[0213]

The standard-voltage generating part 816 has resistors 818 and 820 that are connected in series, and a capacitor 822 that is connected parallel to the resistor 820. Thus, the standard-voltage generating part 816 generates a stable direct-current voltage of about 2 to 3 V as a standard voltage, and supplies it to the high-pass filter 824, the amplifying part 860 and the comparator 836. Thus, voltages of signal waveforms outputted from the high-pass filter 824 and the amplifying part 860 oscillate around the standard voltage.

[0214]

The amplifying part 860 has an operational amplifier 834, and resistors 830 and 832. The operational amplifier 834 and the resistors 830 and 832 are formed as a not-inverting amplifying circuit that amplifies an input signal without inverting and outputs it. The counter electromotive force signal that is outputted from the driving-voltage generating part 850 is inputted to a plus terminal of the operational amplifier 834 via the high-pass filter 824. A minus terminal of the operational amplifier 834 is connected to an output terminal via the negative-feedback resistor 830, and to the standard voltage via the resister 832. Thus, the faint counter electromotive force signal that is outputted from the actuator is amplified around the standard voltage, and then outputted to the comparator 836. The waveform of thus amplified counter electromotive force signal may be indicated as an analogue waveform shown in Fig. 4.

[0215]

The voltage of the counter electromotive force signal outputted from the amplifying part 860 and the standard voltage generated by the standard-voltage generating part 816 are inputted to the comparator 836, and when the voltage of the counter electromotive force signal is higher than the standard voltage, a signal of High is output, and when the voltage of the counter electromotive force signal is lower than the standard voltage, a signal of Low is output. Thus, a digital-waveform counter electromotive force signal is generated. That is, since the output of the operational amplifier 834 oscillates around the standard voltage and the minus terminal of the comparator 836 has the same voltage as the standard voltage, the comparator 836 compares the voltage of the counter electromotive force signal to the standard voltage and outputs the digital-waveform counter electromotive force signal. The comparator 836 outputs the generated digital-waveform counter electromotive force signal to a terminal 844.

[0216]

As described above, further, the supply of the driving voltage signal to the piezoelectric device is carried out by an input of a trigger signal from the terminal 840. The input of the trigger signal may be carried out by a controlling unit 840c. For example, the controlling unit 840c may be provided in an ink-jet recording apparatus or another various kinds of liquid consuming apparatus in which the liquid container is mounted.

[0217]

Fig. 16 shows a circuit structure of the detecting circuit 1100 of Fig. 5. The detection circuit 1100 has the digital circuit 900 and the liquid-existence judging part 1000. The digital circuit 900 has: flip-flop circuits 910 and 918, counters 912 and 920, and NAND gates 914 and 916. The counter 920 maintains the highest value after counting the highest value (1111, 1111), without becoming a value (0000, 0000) even if the next clock pulse is inputted.

[0218]

When a trigger signal is inputted from a terminal 842 to a clock-input pin CLK of the flip-flop circuit 910, the flip-flop circuit 910 outputs a signal, which controls the

counter 912 to start the measurement of the number of pulses in the counter electromotive force signal outputted from the measuring circuit 800, to the counter 912. In addition, when the counter 912 counts eight pulses in the counter electromotive force signal, the flip-flop circuit 910 is cleared via the NAND gate 916. Thus, the flip-flop circuit 910 supplies a signal being High from a timing the trigger signal has been inputted to the eighth pulse of the counter electromotive force signal, to a count-enabling terminal ENP of the counter 912.

[0219]

The counter 912 counts the number of clock pulses only while the signal inputted to the counter-enabling terminal ENP is High. The counter 912 starts to count the number of pulses of the counter electromotive force signal just after the trigger signal has been inputted to the flip-flop circuit 910, and stops counting the number of pulses when the eight pulses are counted so that the signal inputted to the counter-enabling terminal ENP becomes Low. The counter 912 outputs a signal being High from fourth pulse to eighth pulse from an output pin QC to an input pin D of the flip-flop circuit 918.

[0220]

The flip-flop circuit 918 receives the signal being High from the fourth pulse to the eighth pulse, which is outputted from the counter 912, from the input pin D, receives a clock pulse signal having a frequency of 16 MHz, which is inputted through the terminal 846, from a clock-input pin CLK, and then outputs the signal inputted from the input-pin D while synchronizing the signal with the clock pulse signal.

[0221]

[Formula 1]

The counter 920 receives the same clock pulse of 16 MHz as inputted to the flip-flop circuit 918, from a clock-input pin CLK. Thus, the counter 920 operates synchronously with the flip-flop circuit 918, so that it can count the number of pulses of the clock pulse of 16 MHz while the output of the output pin Q is High, that is, from the fourth pulse to the eighth pulse. By counting the number of pulses of the clock pulse of 16 MHz, a time for which the four pulses from the fourth pulse to eighth pulse are generated can be measured. The counter 920 outputs the counted value to the

liquid-existence judging part 1000. In addition, before the output pin Q of the flip-flop circuit 918 becomes High, that is, before the counter 920 operates, an output of an output pin $\overline{Q}$ of the flip-flop circuit 918 and an output of an output pin QB of the counter 912 are processed for a NAND calculation at the NAND gate 914, inputted to a clear-input pin CLR of the counter 920 to clear the counter 920.

[0222]

In the circuit shown in Fig. 16, the number of pulses of the clock pulse of 16 MHz appearing between the 4th pulse and the 8th pulse of the counter electromotive force waveform is counted, however, by adding and/or combining a counting circuit that uses the output of the counter 912 not only time until the 8th pulse with but also any other pulse may be counted. That is, a time between any two counts can be detected.

[0223]

Fig. 17 shows a detailed circuit structure of the liquid-existence judging part 1000 shown in Fig. 16. The liquid-existence judging part 1000 judges whether the liquid exists in the liquid container 1 or not, based on the counted value of the number of clock pulses of 16 MHz appearing between the 4th pulse and the 8th pulse of the counter electromotive force signal, which is outputted by the counter 920. As shown in Fig. 17, the liquid-existence judging part 1000 has an upper-limit register 1011, a lower-limit register 1012, comparators 1014 and 1016, and an AND gate 1018. An upper limit of the counted value is stored in the upper-limit register 1011 and a lower limit of the counted value is stored in the lower-limit register 1012.

[0224]

The comparator 1014 receives the counted value outputted from the digital circuit 900 via a B terminal, and receives the upper limit of the counted value from the upper-limit register 1011 via an A terminal. If the counted value is smaller than the upper limit value, the comparator 1014 outputs a signal being High to the AND gate 1018. On the other hand, if the counted value is larger than the upper limit value, the comparator 1014 outputs a signal being Low to the AND gate 1018. If the counted value is larger than the upper limit value, the frequency of the counter electromotive force waveform is lower than a lower limit thereof, which means that the counter electromotive force

waveform has been measured not normally, that is, there is a possibility that the liquid container is not mounted on the recording apparatus or that the liquid container is surely mounted thereon.

[0225]

On the other hand, the comparator 1016 receives the counted value outputted from the digital circuit 900 via an A terminal, and receives the lower limit of the counted value from the lower-limit register 1012 via a B terminal. If the counted value is larger than the lower limit value, the comparator 1016 outputs a signal being High to the AND gate 1018 and a terminal 1022. On the other hand, if the counted value is smaller than the lower limit value, the comparator 1016 outputs a signal being Low to the AND gate 1018 and the terminal 1022. If the counted value is smaller than the lower limit value, the liquid in the liquid container 1 may not exist at the mounting position of the actuator 106.

[0226]

If both the comparators 1014 and 1016 output respective High signals, that is, if the counted value is smaller than the upper limit value and larger than the lower limit value, the AND gate 1018 outputs a signal being High. In the case, the frequency of the counter electromotive force waveform is lower than an upper limit thereof, so that the liquid in the liquid container 1 exists at the mounting position level of the actuator 106. In addition, since the frequency of the counter electromotive force waveform is higher than an lower limit thereof, it can be seen that the liquid container 1 is surely attached to the recording apparatus and the liquid exists at the mounting position level of the actuator 106. That is, the case wherein the terminal 1020 is High is a normal case wherein the liquid container 1 is surely attached to the recording apparatus and the liquid exists at the mounting position level of the actuator 106.

[0227]

If the comparator 1014 outputs a Low signal and the comparator 1016 outputs a High signal, that is, if the counted value is larger than the upper limit value and larger than the lower limit value, the AND gate 1018 outputs a signal being Low. Then, the signal being HIGH is inputted to the terminal 1022. The case is abnormal because the terminal 1020 is Low and, the case can be judged that the liquid container 1 is not

mounted on the recording apparatus or is surely mounted thereon because the terminal 1022 is High.

[0228]

If the comparator 1014 outputs a High signal and the comparator 1016 outputs a Low signal, that is, if the counted value is smaller than the upper limit value and smaller than the lower limit value, the AND gate 1018 outputs a signal being Low. The case is abnormal because the terminal 1020 is Low and the case can be seen that the liquid doesn't exist at the mounting position level of the actuator 106 because the terminal 1022 is Low.

[0229]

Each component of the measuring circuit 800 and each component of the detecting circuit 1100 further may be independently provided for each actuator. According to such a liquid consumption condition detecting part 1200, the detection of the liquid consumption condition by each actuator may be carried out at the same time. In the case, as described above, the liquid consumption condition can be judged by whether resonance frequencies detected from the two actuators 106A and 106C are the same or not.

[0230]

Fig. 18 shows a manufacturing method of the actuator 106.

In Fig. 18, a plurality of actuators 106 (four actuators 106, in the case of Fig. 18) are formed integrally. If the integrated structure including the plurality of actuators 106 shown in Fig. 18 is cut off separately, an actuator shown in Fig. 19 can be manufactured. If respective piezoelectric devices of the integrated plurality of actuators 106 shown in Fig. 18 are circular, the actuator 106 shown in Fig. 1 can be manufactured when the integrated structure is cut off separately. By forming the plurality of actuators 106 integrally, the plurality of actuators 106 can be manufactured efficiently at the same time and can be conveyed easily.

[0231]

The actuator 106 has a thin plate or a vibrating plate 176, a substrate 178, an elastic-wave generating means or a piezoelectric device 174, a terminal-forming member or an upper electrode terminal 168, and a terminal-forming member or a lower electrode

terminal 170.

[0232]

The piezoelectric device 174 includes a piezoelectric vibrating plate or a piezoelectric layer 160, an upper electrode 164 and a lower electrode 166. The vibrating plate 176 is formed on an upper surface of the substrate 178, and the lower electrode 166 is formed on an upper surface of the vibrating plate 176. The piezoelectric layer 160 is formed on an upper surface of the lower electrode 166, and the upper electrode 164 is formed on an upper surface of the piezoelectric layer 160. Thus, a main part of the piezoelectric layer 160 is formed so as to be sandwiched between a main part of the upper electrode 164 and a main part of the lower electrode 166.

[0233]

In the case of Fig. 18, a plurality of (four in the case of Fig. 18) piezoelectric devices 174 are formed on the vibrating plate 176. A lower electrode 166 is formed on an upper surface of vibrating plate 176, a piezoelectric layer 160 is formed on an upper surface of lower electrode 166, and an upper electrode 164 is formed on an upper surface of piezoelectric layer 160. An upper electrode terminal 168 is formed at an end of the upper electrode 164, and a lower electrode terminal 170 is formed at an end of the lower electrode 166. Then, the four actuators 106 are cut off separately, so that each of the actuators 106 can be used individually.

[0234]

Fig. 19 is a cross sectional view of a portion of an actuator 106 including a rectangular piezoelectric element. Fig. 20 is a cross sectional view of the whole of the actuator 106 shown in Fig. 19.

[0235]

As shown in Fig. 20, the substrate 178 has a through hole 178a at an area facing the piezoelectric device 174. The through hole 178a is sealed by the vibrating plate 176. The vibrating plate 176 is formed by an electric insulating and elastically deformable material, such as alumina, zirconium oxide, and so on.

[0236]

The piezoelectric device 174 is formed on the vibrating plate 176 at a position

corresponding to the through hole 178a. The lower electrode 166 is formed on the vibrating plate 176 to extend from the area of the through hole 178a toward one direction, that is, the left direction in the case of Fig. 20. The upper electrode 164 is formed on the piezoelectric layer 160 to extend from the area of the through hole 178a toward an opposite direction with respect to the lower electrode, that is, the right direction in the case of Fig. 20.

[0237]

The upper electrode terminal 168 and the lower electrode terminal 170 are formed on upper surfaces of an assistance electrode 172 and the lower electrode 166, respectively. The lower electrode terminal 170 is electrically in contact with the lower electrode 166, and the upper electrode terminal 168 is electrically in contact with the upper electrode 164 via the assistance electrode 172, and, signals can be transferred between the piezoelectric device and an outside of the actuator 106. The upper electrode terminal 168 and the lower electrode terminal 170 has a height greater than that of the piezoelectric device 174 putting together the electrodes 164 and 166 and the piezoelectric layer 160.

[0238]

Fig. 21 shows a manufacturing method of the actuator 106 shown in Fig. 18.

At first, a through hole 40a is formed in a green sheet 40 by a press process or a laser-machining process. The green sheet 40 is to be baked in order to become the substrate 178. The green sheet 40 is formed by a material such as ceramics or the like.

[0239]

Then, another green sheet 41 is layered on an upper surface of the green sheet 40. The green sheet 41 is to be baked in order to become the vibrating plate 176. The green sheet 41 is formed by a material such as zirconium oxide or the like.

[0240]

Next, an electric conductive layer 42, a piezoelectric layer 160 and an electric conductive layer 44 are formed in turn on a surface of the green sheet 41 by means of a pressure-membrane-printing method or the like. The electric conductive layer 42 is adapted to become the lower electrode 166, and the electric conductive layer 44 is adapted to become the upper electrode 164.

[0241]

Then, the green sheets 40 and 41, the electric conductive layer 42, the piezoelectric layer 160 and the electric conductive layer 44 thus formed are dried and baked.

[0242]

Spacer members 47 and 48 are members to increase heights of the upper electrode terminal 168 and the lower electrode terminal 170 more than that of the piezoelectric device. The spacer members 47 and 48 are formed by the same material as the green sheet 40 or 41 by a printing process or a layering process. Since the spacer members 47 and 48 are used, an amount of the material for the upper electrode 168 and the lower electrode 170, which is noble metal, can be reduced. In addition, since thicknesses of the upper electrode 168 and the lower electrode 170 can be reduced, the upper electrode 168 and the lower electrode 170 can be printed more precisely, so that the heights thereof can be adjusted more precisely.

[0243]

If a connecting part 44' for the electric conductive layer 44 and the spacer members 47 and 48 are formed at the same time when the electric conductive layer 42 is formed, the upper electrode 168 and the lower electrode 170 can be formed more easily and fixed more strongly. At last, the upper electrode terminal 168 and the lower electrode terminal 170 are formed at opposite end regions of the electric conductive layers 42 and 44. When the upper electrode terminal 168 and the lower electrode terminal 170 are formed, the upper electrode terminal 168 and the lower electrode terminal 170 are formed in order to electrically connected to the piezoelectric layer 160.

[0244]

Fig. 22 shows further another embodiment of an ink cartridge according to the invention. Fig. 22(A) is a cross sectional view of a base portion of the ink cartridge of the embodiment. The ink cartridge of the embodiment has a through hole 1c at a base wall 1a of a container 1 that contains an ink. A base portion of the through hole 1c is sealed by an actuator 650, which forms an ink stagnant area.

[0245]

Fig. 22(B) is a detailed cross sectional view of the actuator 650 and the through

hole 1c shown in Fig. 22(A). Fig. 22(C) shows a plan view of the actuator 650 and the through hole 1c shown in Fig. 22(B). The actuator 650 has a vibrating plate 72 and a piezoelectric device 73 fixed to the vibrating plate 72. The actuator 650 is fixed to the base wall of the container 1 in such a manner that the piezoelectric device 73 faces the through hole 1c via the vibrating plate 72 and a substrate 71. The vibrating plate 72 is elastically deformable and ink-resistant.

[0246]

Depending on an amount of the ink in the container 1, amplitude and frequency of a counter electromotive force generated by residual vibration of the piezoelectric device 73 and the vibrating plate 72 may change. Since the through hole 1c is formed at the position facing the actuator 650, a predetermined minimum amount of the ink is saved in the through hole 1c. Thus, if a characteristic of the vibration of the actuator 650, which is determined by the amount of the ink saved in the through hole 1c, is measured in advance, an ink-end condition of the container 1 can be surely detected.

[0247]

Figs. 23 shows another embodiment of the through hole 1c. In each of Figs. 23(A) to 23(C), a condition wherein an ink K doesn't exist in the through hole 1c is shown on the left side, and a condition wherein the ink K remains in the through hole 1c is shown on the right side. In the embodiment shown in Fig. 22, a side surface of the through hole 1c is formed as a perpendicular wall. In Fig. 23(A), a side surface 1d of a through hole 1c is oblique in a vertical direction, so that the side surface 1d is enlarged inwardly. In Fig. 23(B), a side surface of a through hole 1c consists of an upper step portion 1f and a lower step portion 1e, and the upper step portion 1f is wider than the lower step portion 1e. In Fig. 23(C), the through hole 1c has a groove 1g extending in a direction in which the ink K is easily discharged, that is, a direction toward an ink supplying port 2.

[0248]

According to the through holes 1c shown in Figs. 23(A) to 23(C), the amount of the ink K in the ink stagnant area can be reduced. Thus, M'cav explained with reference to Figs. 1 and 2 can be made smaller than M'max. Thus, a characteristic of the vibration of the actuator 650 in an ink-end condition may be very different from that

in an ink-remaining condition wherein an amount of the ink K sufficient for a printing operation remains in the container 1, therefore, the ink-end condition can be surely detected.

[0249]

Fig. 24 is a perspective view of another embodiment of the actuator. An actuator 660 has a packing 76 outside the through hole 1c of the vibrating plate 72. Caulking holes 77 are formed at an outside periphery of the actuator 660. The actuator 660 is fixed to a container 1 by caulking via the caulking holes 77.

[0250]

Figs. 25(A) and 25(B) are perspective views of still another embodiment of the actuator. In the embodiment, an actuator 670 has a concave-forming substrate 80 and a piezoelectric device 82. A concave 81 is formed on one side surface of the concave-forming substrate 80 by an etching process or the like, and the piezoelectric device 82 is attached on the other side surface thereof. A base portion of the concave 81 among the concave-forming substrate 80 serves as a vibrating area. Thus, a vibrating area of the actuator 670 is defined by a periphery of the concave 81.

[0251]

The actuator 670 is similar to a structure wherein the substrate 178 and the vibrating plate 176 are integrally formed in the actuator 106 shown in Fig. 1. In the case, manufacturing steps for manufacturing the ink cartridge can be shortened, so that manufacturing cost can be reduced. Preferably, a size of the actuator 670 is suitable for the actuator 670 to be buried in the through hole 1c provided in the container 1. Thus, the concave 81 can serve as a cavity. The actuator 106 shown in the embodiment of Fig. 1 may be formed in such a manner that the actuator 106 can be buried in the through hole 1c, similarly to the actuator 670 shown in the embodiment of Fig. 25.

[0252]

Fig. 26 is a perspective view showing a constitution wherein the actuator 106 is formed integrally as a module body 100. The module body 100 is mounted at a predetermined location of a container 1 of an ink cartridge. The module body 100 is structured so as to detect at least changes in the acoustic impedance in an ink solution,

thereby detect the consumption condition of the liquid in the container 1.

[0253]

The module body 100 of this embodiment has a mount portion 101 for mounting the actuator 106 to the container 1. The mount portion 101 of the liquid container has a substrate 102 having an almost rectangular shape in the surface, and a column 116 on the substrate 102, the column 116 containing the actuator 106 that can be vibrated by a driving signal. Further, when the module body 100 is mounted on the ink cartridge, the actuator 106 of the module body 100 is structured so as not to be touched from outside. Thus, the actuator 106 can be protected from external touch. In addition, the edge of the column 116 on the top side is rounded, so that it can be easily fit at the time of mounting into the through hole formed in the ink cartridge.

[0254]

Fig. 27 is an exploded view of the module body 100 shown in Fig. 26. The module body 100 includes the mount portion 101 of the liquid container made of resin, a plate 110, and a receiving portion 105 of the piezoelectric device having a concavity 113 (see Fig. 26). Furthermore, the module body 100 has lead wires 104a and 104b, the actuator 106, and a film 108. It is preferable that the plate 110 is formed from a rust-proof material such as stainless steel or stainless steel alloy.

[0255]

In the column 116 and the substrate 102 included in the mount portion 101, an opening 114 is formed at the center thereof so as to house the lead wires 104a and 104b, and, at the same time, the concavity 113 is formed around the opening 114 so as to house the actuator 106, the film 108, and the plate 110.

[0256]

The actuator 106 is joined to the plate 110 via the film 108, and the plate 110 and the actuator 106 are fixed to the concavity 113 (liquid container mount portion 101). Therefore, the lead wires 104a and 104b, the actuator 106, the film 108, and the plate 110 are attached integrally to the liquid container mount portion 101.

[0257]

The lead wires 104a and 104b are respectively joined to the upper electrode

and lower electrode of the actuator 106, transfer a driving signal to the piezoelectric layer, and transfer a signal of resonance frequency detected by the actuator 106 to the recording apparatus or the like.

[0258]

The actuator 106 temporarily vibrates on the basis of a driving signal transferred from the lead wires 104a and 104b. Further, after the active vibration, residual vibration of the actuator 106 is started so that a counter electromotive force is generated by the vibration. At this time, by detecting a vibration cycle of the counter electromotive force waveform, a resonance frequency corresponding to a liquid consumption condition in the liquid container can be detected.

[0259]

The film 108 bonds the actuator 106 to the plate 110 so as to make the actuator liquid-tight. It is preferable to form the film 108 by polyolefin or the like and to bond by thermal fusion. Since the actuator 106 and the plate 110 are bonded in a surface-to-surface manner via the film 108, there is less variation in the bonded area, thus, a portion other than the vibrating part may not vibrate. Therefore, the vibration characteristic of the actuator 106 does not change even if the actuator 106 is bonded to the plate 110.

[0260]

In addition, the plate 110 is circular, and the opening 114 of the substrate 102 is formed cylindrically. The actuator 106 and the film 108 are formed rectangularly. The lead wires 104a and 104b, the actuator 106, the film 108, and the plate 110 may be attached to the substrate 102 in a removable manner. The substrate 102, the lead wires 104a and 104b, the actuator 106, the film 108, and the plate 110 are arranged symmetrically with respect to a central axis of the module body 100. Further, the centers of the substrate 102, the actuator 106, the film 108, and the plate 110 are arranged almost on the central axis of the module body 100.

[0261]

The area of the opening 114 of the substrate 102, further, is formed larger than the area of the vibration area of the actuator 106. At the position, which is the center of the plate 110, facing the vibration part of the actuator 106, a through hole 112 is

formed. As shown in Figs. 1 and 2, the cavity 162 is formed in the actuator 106 and the through hole 112 and the cavity 162 form an ink stagnant area. It is preferable that the thickness of the plate 110 is smaller than the diameter of the through hole 112 so as to reduce the effect of residual ink. For example, it is preferable that the depth of the through hole 112 is equal to or less than 1/3 of the diameter thereof. The through hole 112 has an almost circular shape symmetrical about the central axis of the module body 100. Further, the area of the through hole 112 is larger than the area of the opening of the cavity 162 of the actuator 106. The periphery of a section of the through hole 112 may be tapered or stepped in the shape. The module body 100 is mounted to the side wall, the top wall, or the bottom wall of the container 1 in such a manner that the through hole 112 is directed inward the container 1. When the ink is consumed and the ink around the actuator 106 is exhausted, the resonance frequency of the actuator 106 is changed greatly, so that changes in the ink level can be detected.

[0262]

Fig. 28 is a perspective view showing another embodiment of the module body. In a module body 400 of this embodiment, a piezoelectric device mounting portion 405 is formed on a liquid container mount portion 401. The liquid container mount portion 401 has a substrate 402 having an almost square surface with round corners, and a cylindrical column 403 formed on the substrate 402. Further, the piezoelectric device mounting portion 405 includes a plate element 406 erected on the column 403 and a concavity 413. In the concavity 413 formed on a side surface of the plate element 406, the actuator 106 is arranged in a vertical attitude. The top end of the plate element 406, further, is chamfered at a predetermined angle so as to be easily fit at the time of mounting in the through hole formed in the ink cartridge.

[0263]

Fig. 29 is an exploded perspective view of the module body 400 shown in Fig. 28. In the same way as with the module body 100 shown in Fig. 26, the module body 400 includes the liquid container mount portion 401 and the piezoelectric device mounting portion 405. The liquid container mount portion 401 has the substrate 402 and the column 403, and the piezoelectric device mounting portion 405 has the plate element

406 and the concavity 413. The actuator 106 is joined to a plate 410, and then fixed to the concavity 413. The module body 400 further includes lead wires 404a and 404b, the actuator 106, and a film 408.

[0264]

In this embodiment, further the plate 410 is rectangular shape, and an opening 414 formed in the plate element 406 is also rectangular shape. The lead wires 404a and 404b, the actuator 106, the film 408, and the plate 410 may be attached to the substrate 402 in a removable manner. The actuator 106, the film 408, and the plate 410 pass the center of the opening 414 and are arranged symmetrically about a central axis extending perpendicularly to a surface of the opening 414. Further, the centers of the actuator 106, the film 408, and the plate 410 are arranged almost on the central axis of the opening 414.

[0265]

The area of a through hole 412 formed at the center of the plate 410 is larger than the area of the opening of the cavity 162 of the actuator 106. The cavity 162 of the actuator 106 and the through hole 412 form an ink stagnant part. It is preferable that the thickness of the plate 410 is smaller than the diameter of the through hole 412, for example, the thickness may be set to 1/3 or less of the diameter of the through hole 412. The through hole 412 has an almost circle shape symmetrical about the central axis of the module body 400. The periphery of a section of the through hole 412 may be tapered or stepped in the shape. The module body 400 can be mounted to the bottom wall of the container 1 in such a manner that the through hole 412 is arranged in the container 1. The actuator 106 is arranged in the container 1 so as to extend in a vertical direction, thus, by changing the height of the substrate 402 and changing the height of the actuator 106 when it is arranged in the container 1, the setting of the point of time of an ink end condition can be easily changed.

[0266]

Fig. 30 shows still another embodiment of the module body. In the same way as with the module body 100 shown in Fig. 26, a module body 500 shown in Fig. 30 includes a liquid container mount portion 501 having a substrate 502 and a column 503.

The module body 500 further includes lead wires 504a and 504b, the actuator 106, a film 508, and a plate 510. In the substrate 502 included in the mount portion 501, an opening 514 is formed at the center thereof so as to house the lead wires 504a and 504b, and a concavity 513 is formed around the opening 514 so as to house the actuator 106, the film 508, and the plate 510. The actuator 106 is fixed to a piezoelectric device mounting portion 505 via the plate 510. Therefore, the lead wires 504a and 504b, the actuator 106, the film 508, and the plate 510 are integrally attached to the liquid container mount portion 501.

[0267]

In the module body 500 of this embodiment, the column 503 whose top surface is vertically inclined is formed on the substrate 502 that has an almost square surface with round corners in the plane. The actuator 106 is arranged on the concavity 513 which is provided at the top surface of the column 503 slantwise in the vertical direction.

[0268]

That is, the top end of the module body 500 is inclined, and the actuator 106 is mounted on the inclined surface thereof. Therefore, when the module body 500 is mounted on the bottom wall or the side wall of the container 1, the actuator 106 is arranged to be inclined against the vertical direction of the container 1. It is desirable to set the inclination angle of the top end of the module body 500 between about 30° and 60° from a viewpoint of detection performance.

[0269]

The module body 500 is mounted on the bottom wall or the side wall of the container 1 in such a manner that the actuator 106 is arranged in the container 1. When the module body 500 is mounted on the side wall of the container 1, the actuator 106 is attached to the container 1 in such a manner that it is directed toward the top side, the bottom side, or a lateral side of the container 1 in an inclined state. On the other hand, when the module body 500 is mounted on the bottom wall of the container 1, it is preferable that the actuator 106 is attached to the container 1 in such a manner that it is directed toward the ink-supplying-port side of the container 1 in an inclined state.

[0270]

Fig. 31 is a cross sectional view of the neighborhood of the bottom of the ink container when the module body 100 shown in Fig. 26 is mounted to the container 1. The module body 100 is mounted so as to pass through the side wall of the container 1. At the junction between the side wall of the container 1 and the module body 100, an O-ring 365 is provided so as to keep the module body 100 and the container 1 liquid-tight. It is preferable that the module body 100 has a column as explained in Fig. 26 so as to enable the sealing by the O-ring.

[0271]

When the top end of the module body 100 is inserted into the container 1, the ink in the container 1 comes in contact with the actuator 106 via the through hole 112 of the plate 110. A resonance frequency of residual vibration of the actuator 106 varies with whether the medium around the vibration part of the actuator 106 is a liquid or a gas, so that an ink consumption condition can be detected by using the module 100.

[0272]

In addition to the module body 100, the module body 400 shown in Fig. 28, the module body 500 shown in Fig. 30, or module bodies 700A, 700B, 750A and 750B or a molded structure 600, which will be shown in Figs. 32 and 33 next, may be mounted in the container 1 to detect the existence of the ink.

[0273]

Figs. 32(A) and 32(B) show other embodiments of the module body 100. The module body 750A shown in Fig. 32(A) has an actuator 106b and a mounting member 360. The module body 750A is attached to the container 1 in such a manner that a front surface thereof substantially conforms to an inside surface of the side wall of the container 1. The actuator 106b includes the piezoelectric layer 160, the upper electrode 164, the lower electrode 166, and the vibrating plate 176. The lower electrode 166 is formed on the upper surface of the vibrating plate 176. The piezoelectric layer 160 is formed on the upper surface of the lower electrode 166 and the upper electrode 164 is formed on the upper surface of the piezoelectric layer 160. Therefore, the piezoelectric layer 160 is formed so as to be sandwiched between the upper electrode 164 and the lower

electrode 166. The piezoelectric layer 160, the upper electrode 164 and the lower electrode 166 form a piezoelectric device. The piezoelectric device is formed on the vibrating plate 176. The piezoelectric device and the vibration area of the vibrating plate 176 are the vibrating part where the actuator actually vibrates. A through hole 385 is formed in the side wall of the container 1. Thus, the ink is contact with the vibrating plate 176 via the through hole 385 of the container 1.

[0274]

Next, an operation of the module body 750A shown in Fig. 32(A) is explained. The upper electrode 164 and the lower electrode 166 transmit a driving signal to the piezoelectric layer 160 and a resonance-frequency signal detected by the piezoelectric layer 160 to the recording apparatus. The piezoelectric layer 160 generates a vibration by the driving signal transmitted by the upper electrode 164 and the lower electrode 166, and then residual vibration remains. Due to the residual vibration, the piezoelectric layer 160 generates a counter electromotive force. Then, the vibration period of the counter electromotive force waveform is counted so that the resonance frequency at that time is detected, thus, it can be detected whether the ink exits or not.

[0275]

In the module body 750A, the surface of the vibrating part of the actuator 106b opposite to the piezoelectric device, that is, as shown in Fig. 32(A), only the vibrating plate 176 can be contact with the ink in the ink container 1. In the module body 750A shown in Fig. 32(A), embedding of the electrodes of the lead wires (104a, 104b, 404a, 404b, 504a, and 504b) shown in Figs. 26 to 30 into the module body is not required. As a result, the molding step is simplified. Further, the module 750A can be exchanged and recycled. In addition, the mounting member 360 protects the actuator 106b, so that the actuator 106b can be protected from external touch.

[0276]

Fig. 32(B) shows another embodiment of the module body. The module body 750B shown in Fig. 32(B) has also an actuator 106b and a mounting member 360. The module body 750B is attached to the container 1 in such a manner that a front surface thereof substantially conforms to an inside surface of the side wall of the container 1.

The actuator 106b includes the piezoelectric layer 160, the upper electrode 164, the lower electrode 166, and the vibrating plate 176. The lower electrode 166 is formed on the upper surface of the vibrating plate 176. The piezoelectric layer 160 is formed on the upper surface of the lower electrode 166 and the upper electrode 164 is formed on the upper surface of the piezoelectric layer 160. Therefore, the piezoelectric layer 160 is formed so as to be sandwiched between the upper electrode 164 and the lower electrode 166. The piezoelectric layer 160, the upper electrode 164 and the lower electrode 166 form a piezoelectric device. The piezoelectric device is formed on the vibrating plate 176. The piezoelectric device and the vibration area of the vibrating plate 176 are the vibrating part where the actuator actually vibrates. A thin wall 380 is provided in the side wall of the container 1. As shown in Fig. 32(B), in the module body 750B, the surface of the vibrating part of the actuator 106b opposite to the piezoelectric device, that is, only the vibrating plate 176 can be contact with the thin wall 380 in the ink container 1. Thus, the vibrating part of the actuator 106b vibrates residually together with the thin wall 380.

[0277]

Next, an operation of the module body 750B shown in Fig. 32(B) is explained. The upper electrode 164 and the lower electrode 166 transmit a driving signal to the piezoelectric layer 160 and a resonance-frequency signal detected by the piezoelectric layer 160 to the recording apparatus. The piezoelectric layer 160 generates a vibration by the driving signal transmitted by the upper electrode 164 and the lower electrode 166, and then vibrates residually with the resonance period. Because the vibrating plate 176 is contact with the thin wall 380 of the container 1, the vibrating part of the actuator 106b residual vibrates together with the thin wall 380. The inside surface of the thin wall 380 is contact with the ink, thus, when the actuator 106b vibrates residually together with the thin wall 380, the resonance frequency and the amplitude of the residual vibration depend on the amount of the residual ink. Due to the residual vibration, the piezoelectric layer 160 generates a counter electromotive force. Then, the vibration period of the counter electromotive force waveform is counted so that the resonance frequency at that time is detected, thus, the amount of the residual ink can be detected.

[0278]

In the module body 750B shown in Fig. 32(B), embedding of the electrodes of the lead wires (104a, 104b, 404a, 404b, 504a, and 504b) shown in Figs. 26 to 30 into the module body is not required. As a result, the molding step is simplified. Further, the module body 750B can be exchanged and recycled. In addition, the mounting member 360 protects the actuator 106b, so that the actuator 106 can be protected from external touch.

[0279]

Fig. 33(A) shows a cross sectional view of the ink container when the module body 700B is mounted in the container 1. In the case of Fig. 33(A), the module body 700B is used as one of the mounting structures. The module body 700B is mounted to the container 1 in such a manner that a liquid container mount portion 360 is projected into the container 1. A through hole 370 is formed in a mounting plate 350, and the through hole 370 and the vibration part of the actuator 106 are opposite to each other. Further, a hole 382 is formed in the bottom wall of the module body 700B to form a piezoelectric device mounting portion 363. The actuator 106b is arranged so as to block the hole 382.

[0280]

Therefore, the ink is in contact with the vibrating plate 176 via the hole 382 of the piezoelectric device mounting portion 363 and the through hole 370 of the mounting plate 350. The hole 382 of the piezoelectric mounting portion 363 and the through hole 370 of the mounting plate 350 form an ink stagnant area. The piezoelectric device mounting portion 363 and the actuator 106b are fixed by the mounting plate 350 and a film member. Further, at the connecting part of the liquid container mount portion 360 and the container 1, a sealing structure 372 is installed. The sealing structure 372 may be formed by a plastic material such as synthetic resin or may be formed by an O-ring. The module body 700B and the container 1 shown in Fig. 33(A) are independently with each other, however, as shown in Fig. 33(B), the piezoelectric device mounting portion of the module body 700B may be composed of a part of the container 1.

[0281]

The module body 700B shown in Fig. 33(A) does not require embedding of the lead wires shown in Figs. 26 to 30 into the module body. As a result, the molding step is simplified. Further, the module body 700B can be exchanged and recycled.

[0282]

The ink may adhere to the top wall or the side wall of the container 1 when the ink cartridge is swung. Such ink may drop from the top wall or the side wall of the container 1 and may come in contact with the actuator 106b, so that the actuator 106b may malfunction. However, if the mount portion 360 of the module body 700B is projected into the container 1, the actuator 106b will not malfunction due to the ink dropping from the top wall or the side wall of the container 1.

[0283]

Further, according to the example shown in Fig. 33(A), the vibrating plate 176 and a portion of the mounting plate 350 are mounted in the container 1 in such a manner that they alone come in contact with the ink in the container 1.

[0284]

Fig. 33(B) shows a cross sectional view of an ink container of another embodiment when the actuator 106b is mounted in the container 1. In the ink cartridge of the embodiment shown in Fig. 33(B), a protective member 361 is attached to the container 1 separately from the actuator 106b. Therefore, the protective member 361 and the actuator 106b are not integrated as a module body. However, the protective member 361 can protect the actuator 106b from being touched by user's hand. A hole 380 is formed in the side wall of the container 1 correspondingly to a front surface of the actuator 106b.

[0285]

The actuator 106b includes the piezoelectric layer 160, the upper electrode 164, the lower electrode 166, the vibrating plate 176, and the mounting plate 350. The vibrating plate 176 is formed on the upper surface of the mounting plate 350, and the lower electrode 166 is formed on the upper surface of the vibrating plate 176. And, the piezoelectric layer 160 is formed on the upper surface of the lower electrode 166, and

the upper electrode 164 is formed on the upper surface of the piezoelectric layer 160. Therefore, the main part of the piezoelectric layer 160 is sandwiched between the main part of the upper electrode 164 and the main part of the lower electrode 166. The circular parts, which are the respective main parts of the piezoelectric layer 160, the upper electrode 164, and the lower electrode 166, form a piezoelectric device. The piezoelectric device is formed on the vibrating plate 176. The piezoelectric device and the vibration area of the vibrating plate 176 are the vibrating part where the actuator actually vibrates. The through hole 370 is formed in the mounting plate 350. Therefore, the ink is in contact with the vibrating plate 176 via the hole 380 of the container 1 and the through hole 370 of the mounting plate 350. The hole 380 of the container 1 and the through hole 370 of the mounting plate 350 form an ink stagnant area. According to the example shown in Fig. 33(B), further the actuator 106b is protected from contact with the outside by the protective member 361.

[0286]

In addition, the actuator 106b and the mounting plate 350 shown in the examples in Figs. 33(A) and 33(B) can be replaced with the actuator 106 having the substrate 178 shown in Fig. 1.

[0287]

Fig. 33(C) shows an embodiment having a molded structure 600 including the actuator 106b. According to the example of Fig. 33(C), the molded structure 600 is used as one of a mounting structure. The molded structure 600 has the actuator 106b and a molding part 364. The actuator 106b and the molding part 364 are integrally formed. The molding part 364 is formed by a plastic material such as silicone resin and the like. The molding part 364 is formed so as to have two legs extended from the actuator 106b. Legs of the molding part 364 has a lead wire 362 therein. To fix the molding part 364 and the container 1 in a liquid-tight manner, the ends of the two legs of the molding part 364 are formed semispherically outside the container 1. The molding part 364 is mounted to the container 1 in such a manner that the actuator 106b is projected into the container 1. Thus, the vibrating part of the actuator 106b comes in contact with the ink in the container 1. The upper electrode 164, the piezoelectric layer 160 and the

lower electrode 166 of the actuator 106b are protected from contact with the ink by the molding part 364.

[0288]

The molded structure 600 shown in Fig. 33(C) does not require the sealing structure 372 between the molding part 364 and the container 1, so that the ink hardly leaks from the container 1. Further, the molded structure 600 has a shape which is not projected outward from the container 1, so that the actuator 106b is protected from contact with the outside. Further, in the molded structure 600, the molding part 364 is projected into the container 1, so that the actuator 106b will not malfunction even if the ink drops from the top wall or the side wall of the container 1.

[0289]

In addition, each module body described above is constituted in such a manner that has one actuator, however, each module body may have two actuators may be possible. Fig. 34 schematically shows such a case. If the module body 4000 shown in Fig. 34 is used, as shown in Fig. 35, the liquid surface level can be controlled extremely precisely to a predetermined level LL, as mentioned above with reference to Figs. 10 and 11. In addition, equipment can be made more compact and accuracy of its positioning can be improved, compared with a case wherein two actuators are independently arranged.

[0290]

The above explanation is given to the carriage and the ink cartridge mounted on the carriage, that is, not integrally formed with the carriage, when the actuator 106 is attached to the carriage or the ink cartridge. However, the actuator 106 may be attached to an ink tank integrally formed with the carriage, which ink tank may be mounted on an ink-jet recording apparatus together with the carriage. In addition, the actuator 106 may be attached to an off-carriage type of ink tank, which is not integrally formed with the carriage and is adapted to supply ink to the carriage via a tube or the like. Furthermore, the actuator according to the present invention may be attached to a part corresponding to an ink cartridge of a replaceable structure wherein a recording head and an ink container are integrally formed.

[0291]

In addition, the recording apparatus controllers 2000, 2004 and 2006 and/or each component thereof and the controlling unit 840c (see Fig. 15) can be materialized by a computer system. Here, a program for materializing the above each component or the like in the computer system, and a storage medium 201 (see Fig. 5) storing the program capable of being read by a computer, should be protected by the application as well.

[0292]

Further, if the above component or the like is materialized by a program such as OS executed by a computer system, a program including various commands for controlling the program of the OS and/or a storage medium 202 storing the program, should be protected by the application as well.

[0293]

The storage medium 201, 202, here, may be not only a substantial object such as a floppy disk or the like, but also a network for transmitting various signals.

[0294]

The example of the liquid may be glue, nail polish or the like, instead of the ink.

[0295]

The embodiments of the present invention are explained above, and the scope of the present invention however, is not limited to the range described in the embodiments aforementioned. Various changes or improvements can be applied to the embodiments aforementioned. It is obvious from the description in the claims that any configuration to which such various changes or improvements are applied is included in the scope of the present invention.

[0296]

[Advantages of the Invention]

According to the present invention, so-called a "liquid-full" condition of the containing space can be detected highly reliably. The present invention is very effective for a liquid replenishment operation to fill the containing space to a "liquid-full" condition.

[0297]

Alternatively, according to the present invention, a "liquid-full" condition and a

"liquid-end" condition of the containing space can be detected highly reliably. This feature is very effective for a liquid replenishment operation to fill the containing space to a "liquid-full" condition after a "liquid-end" condition has been detected.

[0298]

Alternatively, according to the present invention, it can be detected highly reliably whether a liquid surface level in the containing space exists in a predetermined area defined by the two vibrating parts or not. The present invention is very effective for maintaining a liquid surface level at a substantially fixed point to maintain a liquid-head pressure at a substantially fixed point.

[Brief Description of the Drawings]

[Fig. 1]

Drawings showing details of an actuator 106.

[Fig. 2]

A drawing showing the periphery of the actuator 106 and equivalent circuits thereof.

[Fig. 3]

Drawings showing a relationship between ink density and resonance frequency of ink detected by the actuator 106.

[Fig. 4]

Drawings showing a counter electromotive force waveform of the actuator 106.

[Fig. 5]

A diagram schematically showing construction of a recording apparatus controller 2000, which can detect a consumption condition of a liquid in a liquid container 1 by an actuator detecting changes in an acoustic impedance and that can control an ink-jet recording apparatus based on the detected result.

[Fig. 6]

A view showing mounting positions of the actuators in the case of Fig.5.

[Fig. 7]

A schematic view showing an example of ink replenishing unit.

[Fig. 8]

A block diagram, similar to Fig. 5, of another embodiment modified in an actuator-setting manner.

[Fig. 9]

A view showing a mounting position of the actuator in the case of Fig. 8.

[Fig. 10]

A diagram, similar to Fig. 5, of another embodiment modified in an actuator-setting manner.

[Fig. 11]

A schematic view showing mounting positions of the actuators in the case of Fig. 10.

[Fig. 12]

A diagram of still another embodiment wherein the recording apparatus controller 2000 shown in Fig. 5 is modified.

[Fig. 13]

A block diagram of still another embodiment wherein the recording apparatus controller 2004 shown in Fig. 12 is modified.

[Fig. 14]

A flowchart showing an operation procedure of the recording apparatus controller 2006 shown in Fig. 13.

[Fig. 15]

A diagram showing a circuit structure of the measuring circuit 800.

[Fig. 16]

A diagram showing a circuit structure of the detecting circuit 1100.

[Fig. 17]

A diagram showing a detailed circuit structure of the liquid-existence judging part 1000 shown in Fig. 16.

[Fig. 18]

A perspective view of another embodiment of the actuator 106.

[Fig. 19]

A cross sectional view of a portion of the actuator 106 shown in Fig. 18.

[Fig. 20]

A cross sectional view of the whole of the actuator 106 shown in Fig. 19.

[Fig. 21]

A perspective view for explaining a manufacturing method of the actuator 106 shown in Fig. 18.

[Fig. 22]

Cross sectional views and a plan view of another embodiment of the ink cartridge.

[Fig. 23]

Cross sectional views showing other embodiments of the through hole 1c.

[Fig. 24]

A perspective view of another embodiment of the actuator 660.

[Fig. 25]

A perspective view and a cross sectional view of another embodiment of the actuator 670.

[Fig. 26]

A perspective view showing the module 100.

[Fig. 27]

An exploded view showing constitution of the module body 100 shown in Fig. 26.

[Fig. 28]

A perspective view showing another embodiment of the module body 100.

[Fig. 29]

An exploded view showing constitution of the module body 400 shown in Fig. 28.

[Fig. 30]

A view showing still another embodiment of the module body 100.

[Fig. 31]

A drawing showing an example of the cross section when the module body 100 shown in Fig. 26 is mounted to the ink container 1.

[Fig. 32]

Views showing still other embodiments of the module body 100.

[Fig. 33]

Views showing still other embodiments of the module body 100.

[Fig. 34]

A schematic view of a module body with two built-in actuators.

[Fig. 35]

A schematic view showing a mounting position of the module of Fig. 34.

[Description of the Reference Numerals]

1, 1': Containers

1a: Base wall

1b: Side wall

1c, 40a: Through holes

1e, 1f: Step portions

1g, 1h: Grooves

2: Ink supplying port

40, 41: Green sheets

42, 44: Conductive layers

44': Connecting part

47, 48: Spacer members

67: Plate

68: Float

71: Adhesive layer

78, 80, 178: Substrates

73, 82: Piezoelectric vibrating plates

74, 75: Ink absorbers

76: Packing

77: Caulking hole

81: Concavity

100, 400, 500, 700: Module bodies

101, 401, 501: Liquid container mount portions

102: Substrate

104, 362: Lead wires

105, 405, 505: Piezoelectric device mount portions

106, 106b, 650, 660, 670: Actuators

106A, 106C: Actuators

SWA, SWC: Semiconductor switches

108: Film

110: Plate

112, 412, 370: Through holes

113: Concavity

114: Opening

116: Column

160: Piezoelectric layer

162: Cavity

164: Upper electrode

166: Lower electrode

168: Upper electrode terminal

170: Lower electrode terminal

172: Auxiliary electrode

174: Piezoelectric device

176: Vibrating plate

180: Ink cartridge

181: Air supplying port

182: Ink inlet portion

183: Ink inlet port

184: Holder

185: Air inlet port

186: Head plate

187: Ink supplying port

188: Nozzle plate

190: Nozzle

192: Wave prevention wall

194: Ink container

194a: Bottom wall

194b: Side wall

194c: Top wall

212: Partition

213, 213a, 213b: Containing chambers

214: Buffer

216, 216a, 216b: Porous members

220: Ink cartridge

222: First partition

224: Second partition

225a: First containing chamber

225b: Second containing chamber

227: Capillary tube

228: Check valve

230: Ink supplying port

232: Valve

232a: Vane

233: Ventilation hole

235: Spring

242: Porous member

250: Carriage

252: Recording head

254: Ink supplying needle

256: Sub-tank unit

258, 258': Convexities

260, 260’: Elastic wave generating means

262: Ink chamber

266: Membrane valve

270: Valve body

272: Ink cartridge

274: Container

274a: Bottom wall

274b: Side wall

276: Ink supplying port

278: Concavity

280, 280’: Gelatinizing materials

282: Packing

284: Spring

286: Valve body

288: Semiconductor storage means

290: Container

290a: Bottom wall

292, 294, 296: Ink chambers

298, 300, 302: Ink supplying ports

304, 306, 308: Gelatinizing materials

310, 312, 314: Concavities

316: Plate

318: Float

350: Mounting plate

360: Liquid container mount portion

364: Molding part

372: Sealing structure

402, 502: Substrate

403, 503: Columns

404, 504: Lead wires

408, 508: Films

410, 510: Plates

413, 513: Concavities

414, 514: Openings

600: Mold structure

606: Actuator

610: Circuit substrate

612: Terminal

800: Measurement circuit portion

810: NPN transistor

812: PNP transistor

816: Standard-voltage generating part

818, 820, 828, 830, 832: Resistors

822, 826: Capacitors

824: High-pass filter

834, 840, 842, 844, 846: Terminals

836: Comparator

840c: Controller

850: Driving-voltage generating part

860: Amplifying part

900: Digital circuit

910, 918: Flip-flop circuits

912, 920: Counters

914, 916: NAND gates

1000: Liquid-existence judging part

1010: Liquid consumption condition amending part

1011: Upper-limit register

1012: Lower-limit register

1014, 1016: Comparators

1018: NAND gate

1020, 1022: Terminals

1100, 1104: Detecting circuits

1200, 1210: Liquid consumption condition detecting parts

1300: Head part

1400: Controlling part

1402: Recording-apparatus-operation controlling part

1404: Display processing part

1406: Printing-operation controlling part

1408: Ink-replenishment processing part

1410: Ink-cartridge-exchange processing part

1412: Printing-data-storing processing part

1414: Printing-data storing part

1416: Display

1418: Speaker

1420: Printing part

1422: Ink replenishing unit

1424: Cartridge exchanging unit

1432: Cleaning driver

1434: Pump

1436: Cleaning part

1440: Head driver

1442: Cleaning controller

1444: Information-storage controlling circuit

1450: Liquid-jetting counter

1452: Liquid-consumption-volume calculating part

1500, 1502, 1506: Controlling circuits

2000, 2004, 2006: Recording apparatus controllers

3001: Carriage

3002: Guide member

3003: Ink-supplying unit

3004: Recording head

3005: Ink cartridge

3006: Cartridge holder

3007: Ink replenishing unit

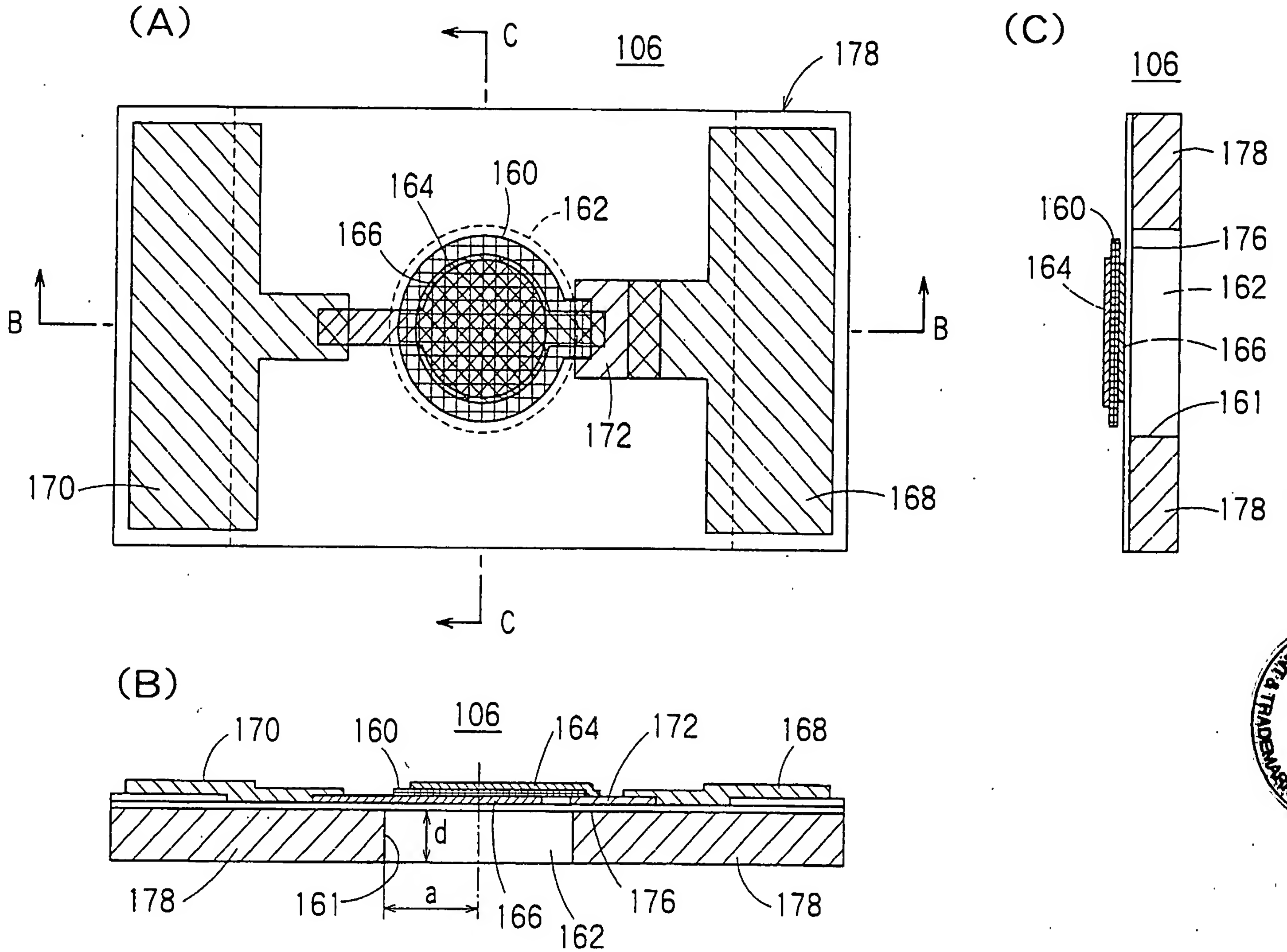
3008: Tube

3009: Ink pouring port

3010: Pump unit

3021: Atmospheric open part

4000: Module body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178
C
B
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160
162
166
172
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(C)
106
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162
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166
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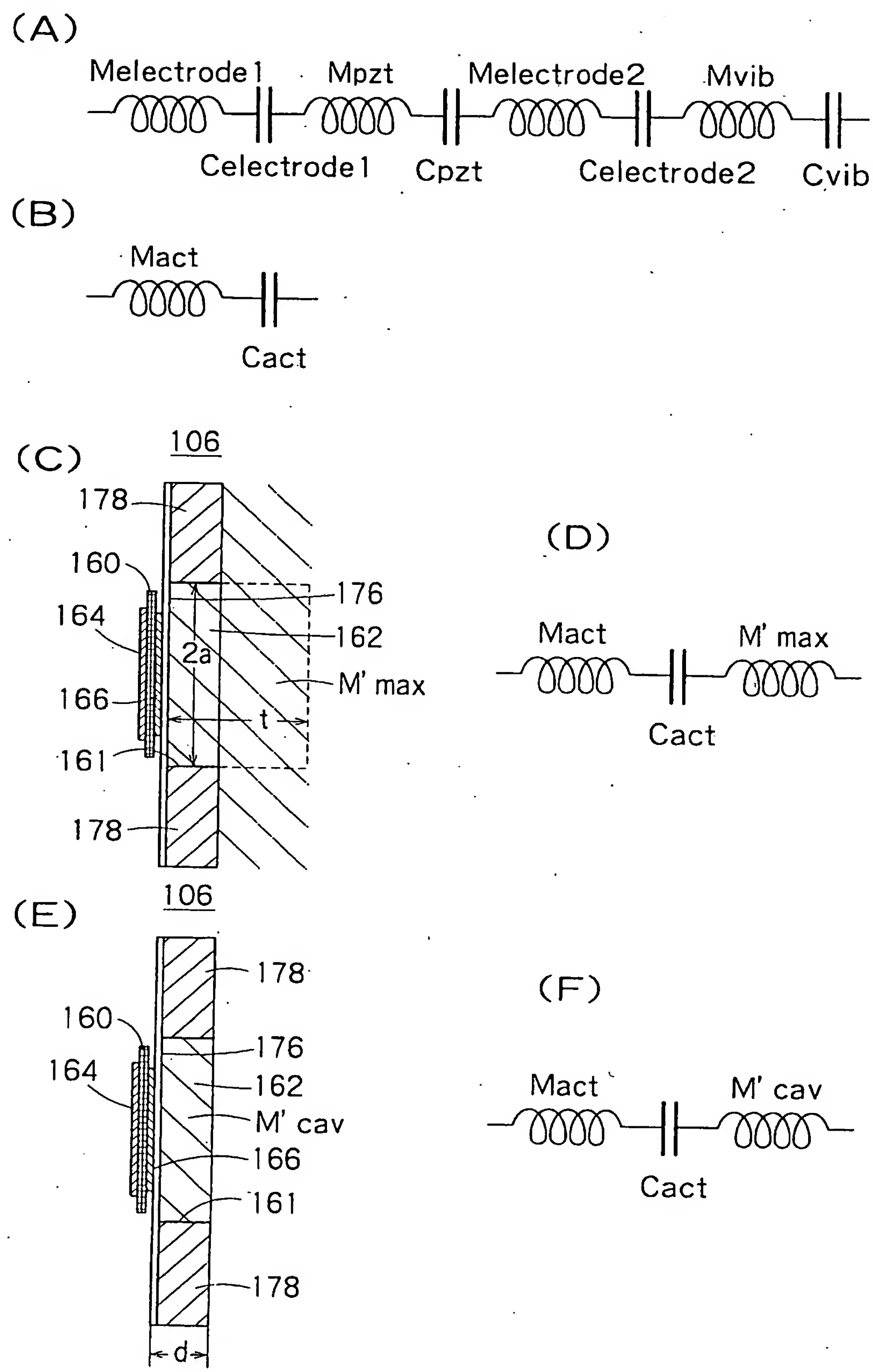
176
178
Fig. 1


(A)
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Mpzt
Melectrode2
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Celectrode1
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106
178
160
164
166
161
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176
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M' max
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(D)
Mact
M' max
Cact
(E)
106
160
164
178
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162
M' cav
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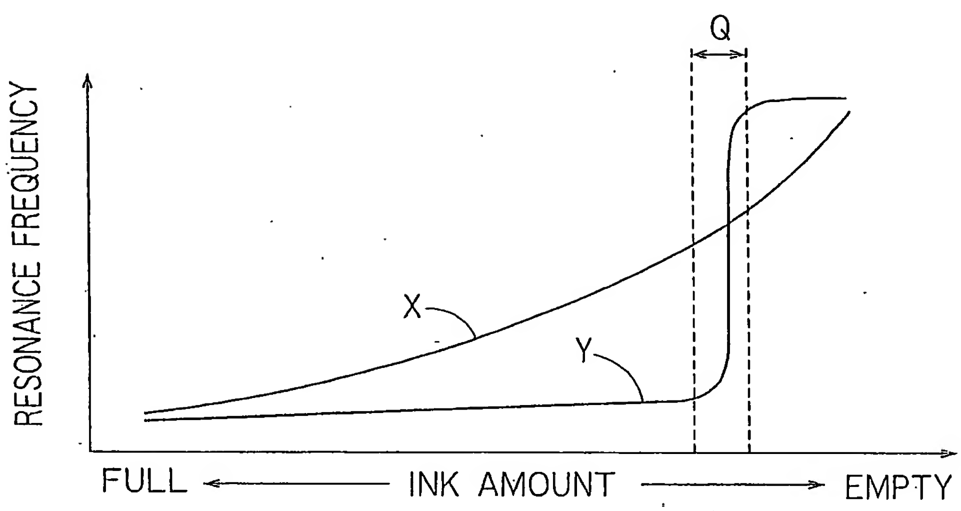
161
178
d
(F)
Mact
M' cav
Cact

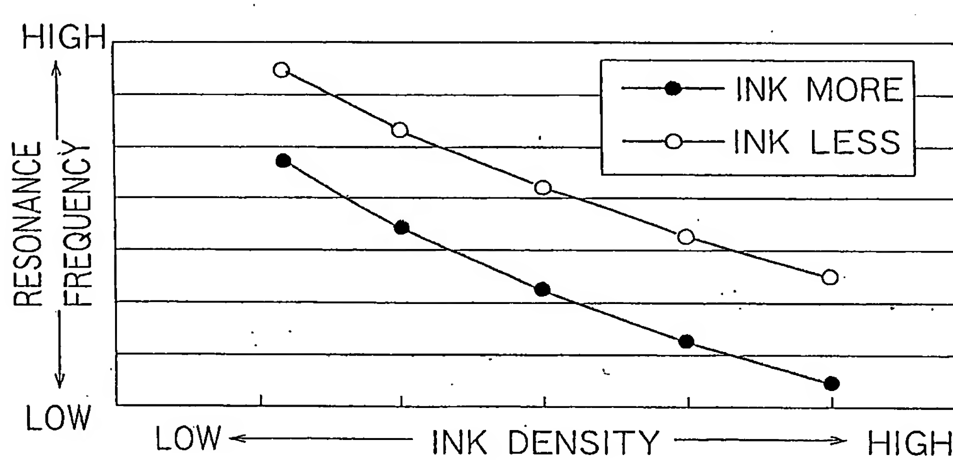
Fig. 2

(A)



Q
RESONANCE FREQUENCY
X
Y
FULL
INK AMOUNT
EMPTY

(B)



HIGH
RESONANCE FREQUENCY
LOW
INK MORE
INK LESS
LOW
INK DENSITY
HIGH

Fig. 3

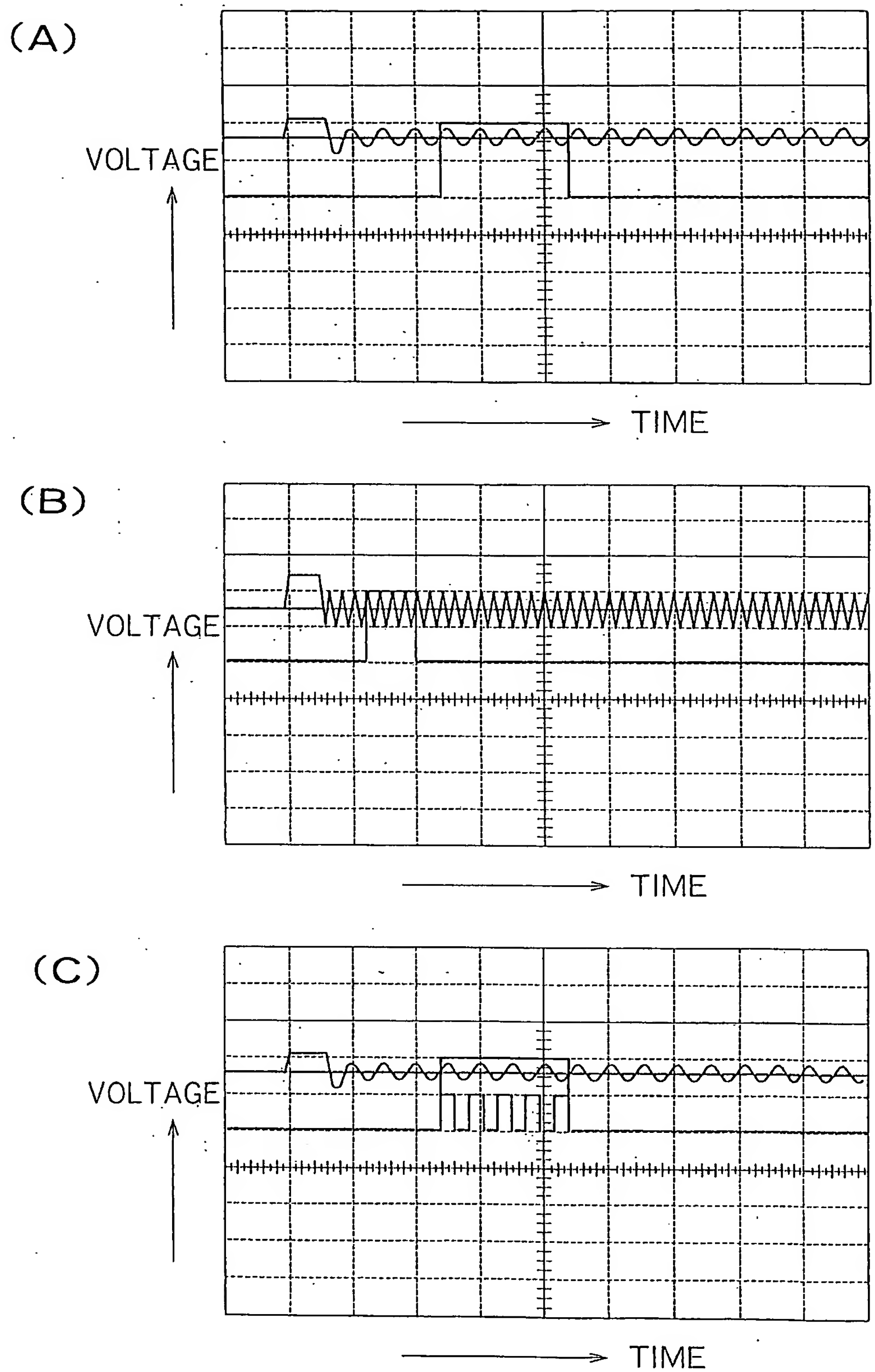
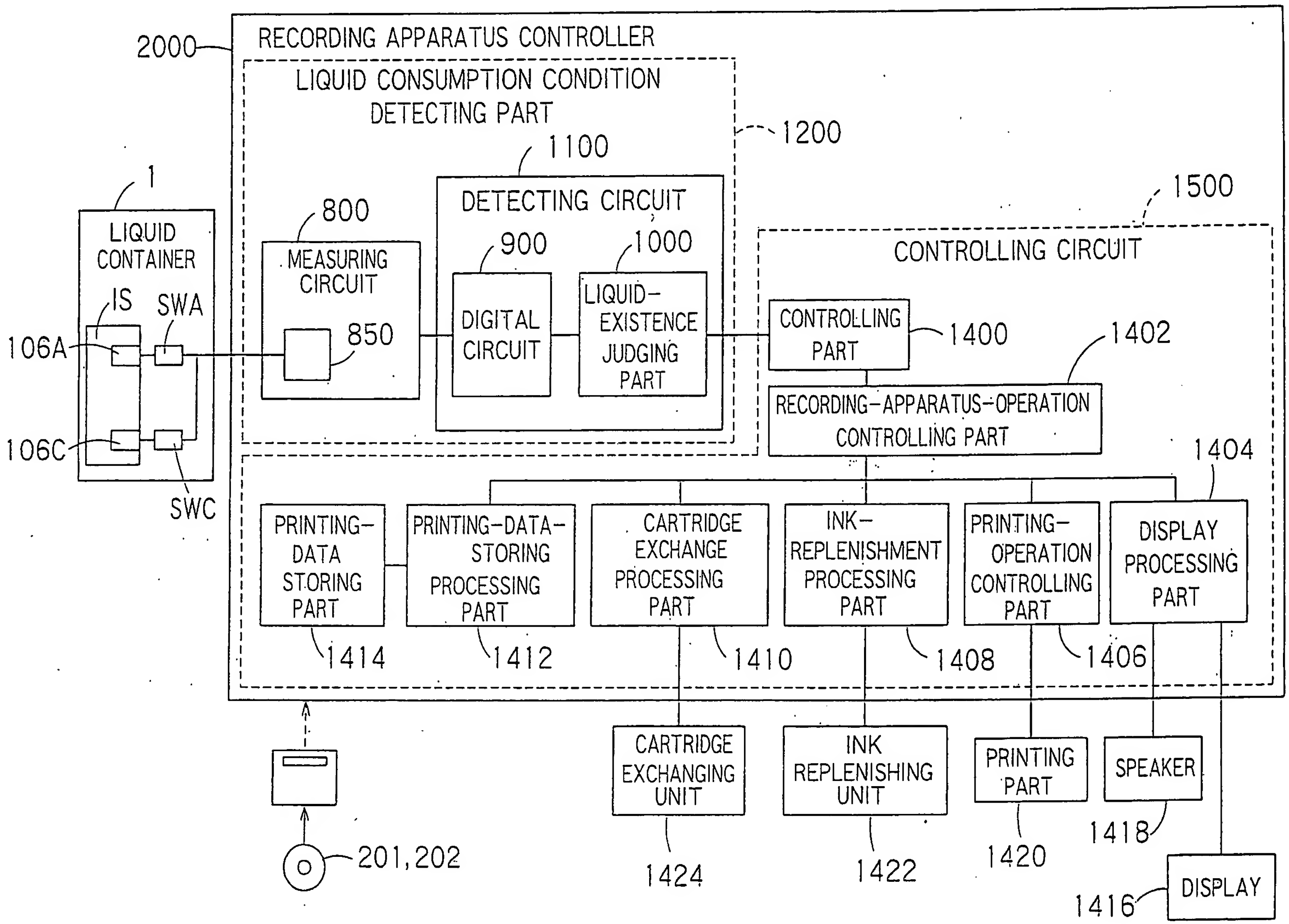


Fig. 4



2000
RECORDING APPARATUS CONTROLLER
LIQUID CONSUMPTION CONDITION DETECTING PART
1200
1100
DETECTING CIRCUIT
1
LIQUID CONTAINER
IS
SWA
106A
106C
SWC
800
MEASURING CIRCUIT
850
900
DIGITAL CIRCUIT
1000
LIQUID-EXISTENCE JUDGING PART
1500
CONTROLLING CIRCUIT
CONTROLLING PART
1400
1402
RECORDING-APPARATUS-OPERATION CONTROLLING PART
1404
PRINTING-DATA STORING PART
1414
PRINTING-DATA-STORING PROCESSING PART
1412
CARTRIDGE EXCHANGE PROCESSING PART
1410
INK-REPLENISHMENT PROCESSING PART
1408
PRINTING-OPERATION CONTROLLING PART
1406
DISPLAY PROCESSING PART
CARTRIDGE EXCHANGING UNIT
1424
INK REPLENISHING UNIT
1422
PRINTING PART
1420
SPEAKER
1418
DISPLAY
1416
201,202

Fig. 5

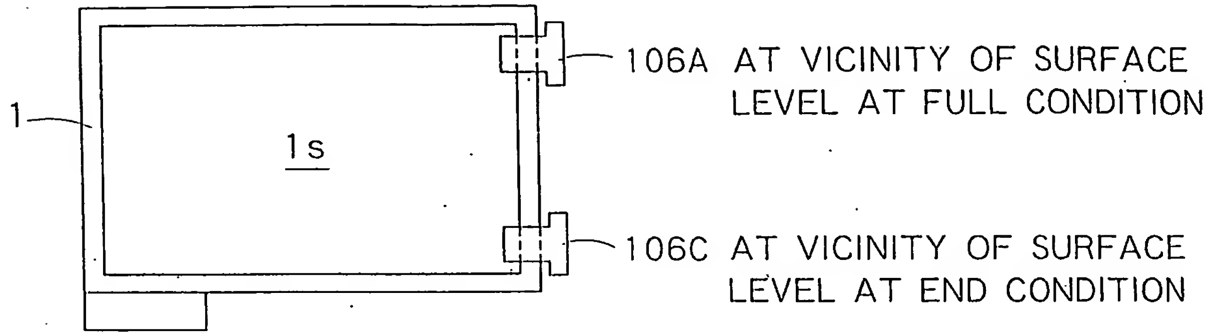

1
1s
106A AT VICINITY OF SURFACE LEVEL AT FULL CONDITION
106C AT VICINITY OF SURFACE LEVEL AT END CONDITION

Fig. 6

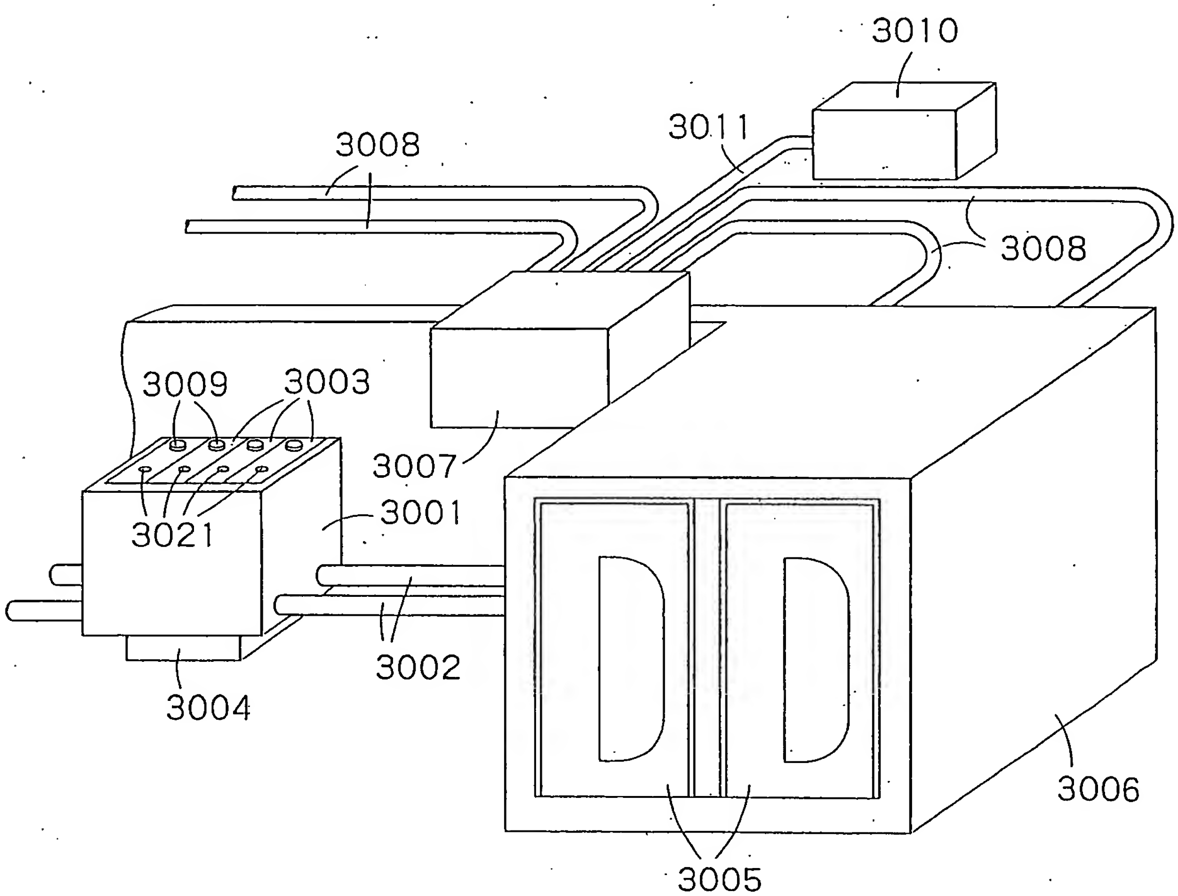

3010
3011
3008
3008
3009
3003
3007
3001
3021
3002
3004
3006
3005

Fig. 7

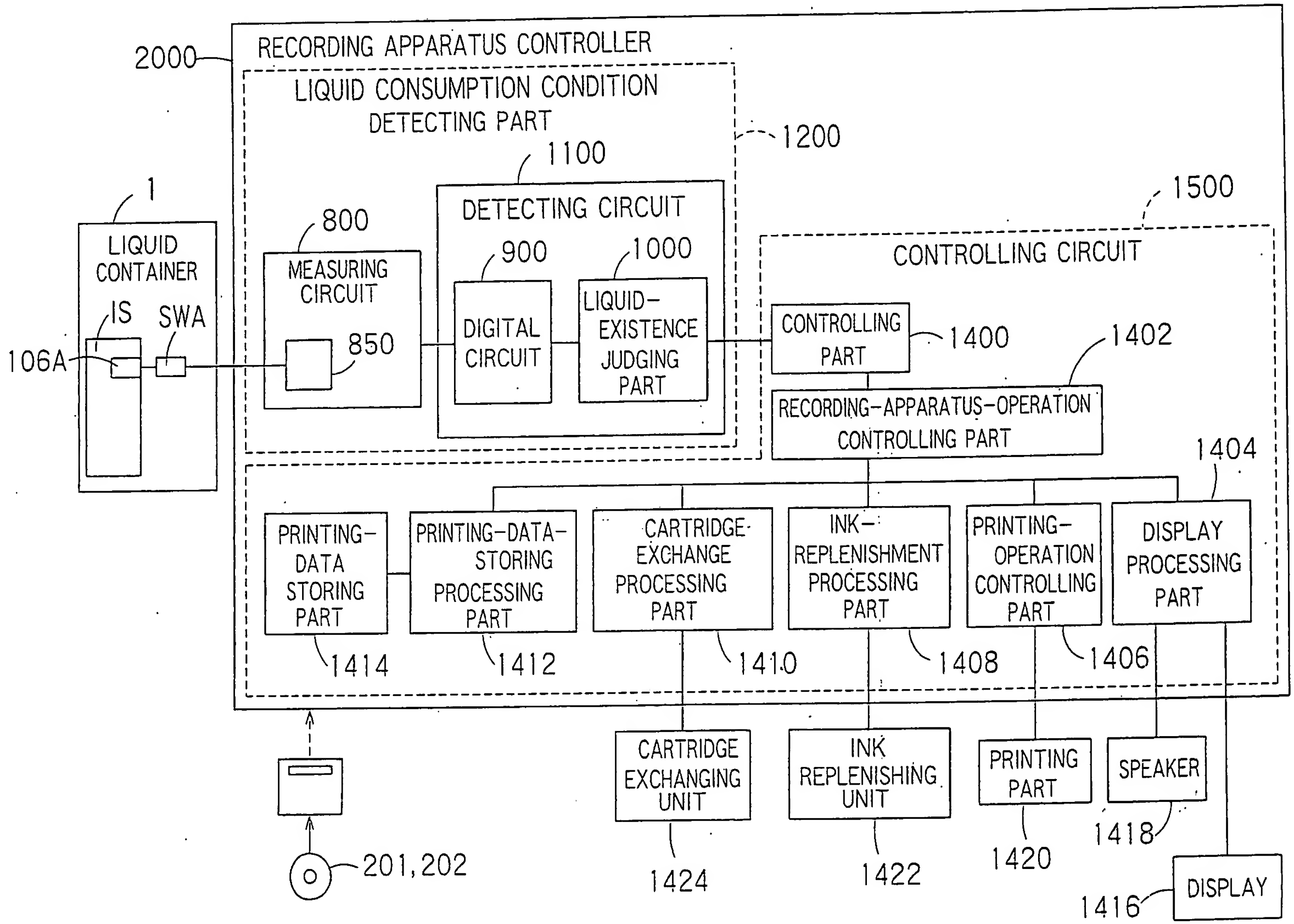

2000
RECORDING APPARATUS CONTROLLER
LIQUID CONSUMPTION CONDITION DETECTING PART
1200
1100
DETECTING CIRCUIT
1500
1
LIQUID CONTAINER
IS
SWA
106A
800
MEASURING CIRCUIT
850
900
DIGITAL CIRCUIT
1000
LIQUID-EXISTENCE JUDGING PART
CONTROLLING CIRCUIT
CONTROLLING PART
1400
1402
RECORDING-APPARATUS-OPERATION CONTROLLING PART
1404
PRINTING-DATA STORING PART
PRINTING-DATA-STORING PROCESSING PART
CARTRIDGE EXCHANGE PROCESSING PART
INK-REPLENISHMENT PROCESSING PART
PRINTING-OPERATION CONTROLLING PART
DISPLAY PROCESSING PART
1414
1412
1410
1408
1406
CARTRIDGE EXCHANGING UNIT
INK REPLENISHING UNIT
PRINTING PART
SPEAKER
1418
201,202
1424
1422
1420
DISPLAY
1416

Fig. 8

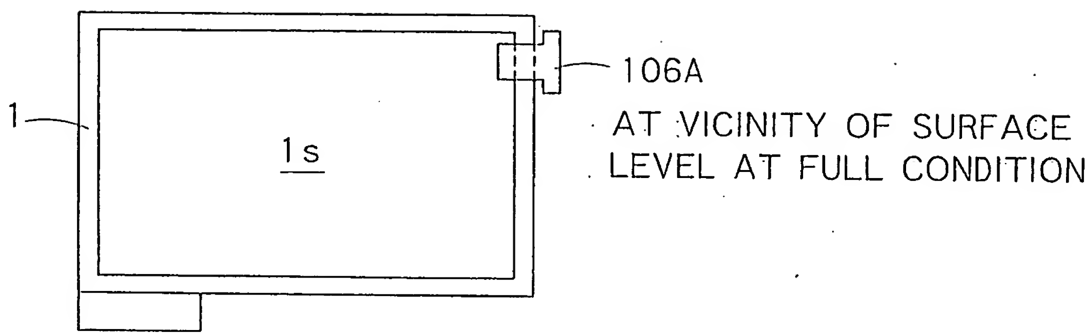
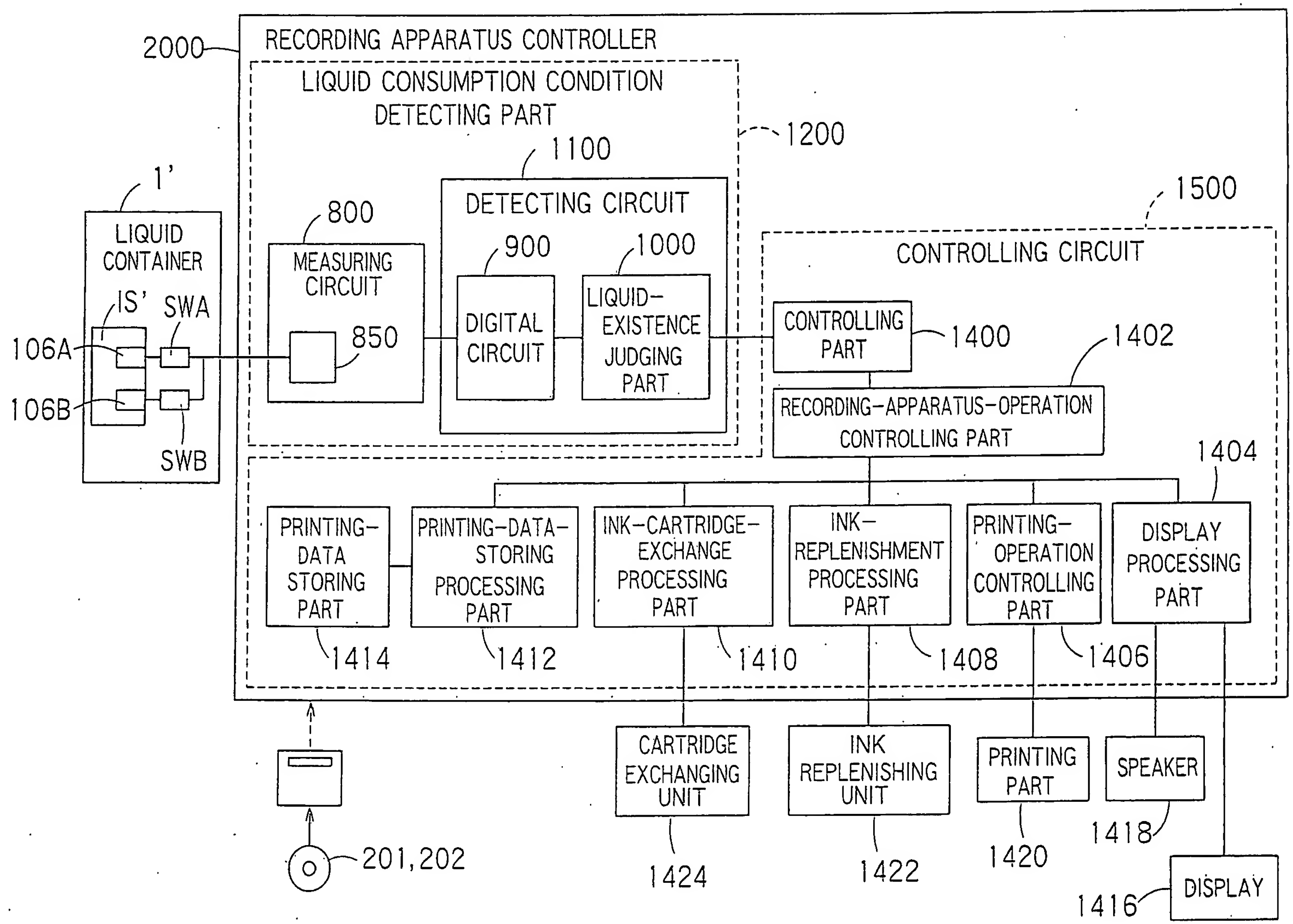


Fig. 9



RECORDING APPARATUS CONTROLLER
2000
LIQUID CONSUMPTION CONDITION DETECTING PART
1200
1100
DETECTING CIRCUIT
1500
CONTROLLING CIRCUIT
1'
LIQUID CONTAINER
800
MEASURING CIRCUIT
850
900
DIGITAL CIRCUIT
1000
LIQUID-EXISTENCE JUDGING PART
IS'
SWA
SWB
106A
106B
CONTROLLING PART
1400
1402
RECORDING-APPARATUS-OPERATION CONTROLLING PART
1404
PRINTING-DATA STORING PART
PRINTING-DATA-STORING PROCESSING PART
INK-CARTRIDGE-EXCHANGE PROCESSING PART
INK-REPLENISHMENT PROCESSING PART
PRINTING-OPERATION CONTROLLING PART
DISPLAY PROCESSING PART
1414
1412
1410
1408
1406
CARTRIDGE EXCHANGING UNIT
INK REPLENISHING UNIT
PRINTING PART
SPEAKER
DISPLAY
201,202
1424
1422
1420
1418
1416

Fig. 10

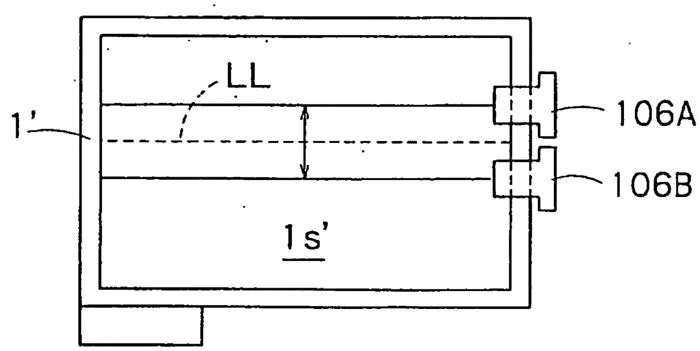


Fig. 11

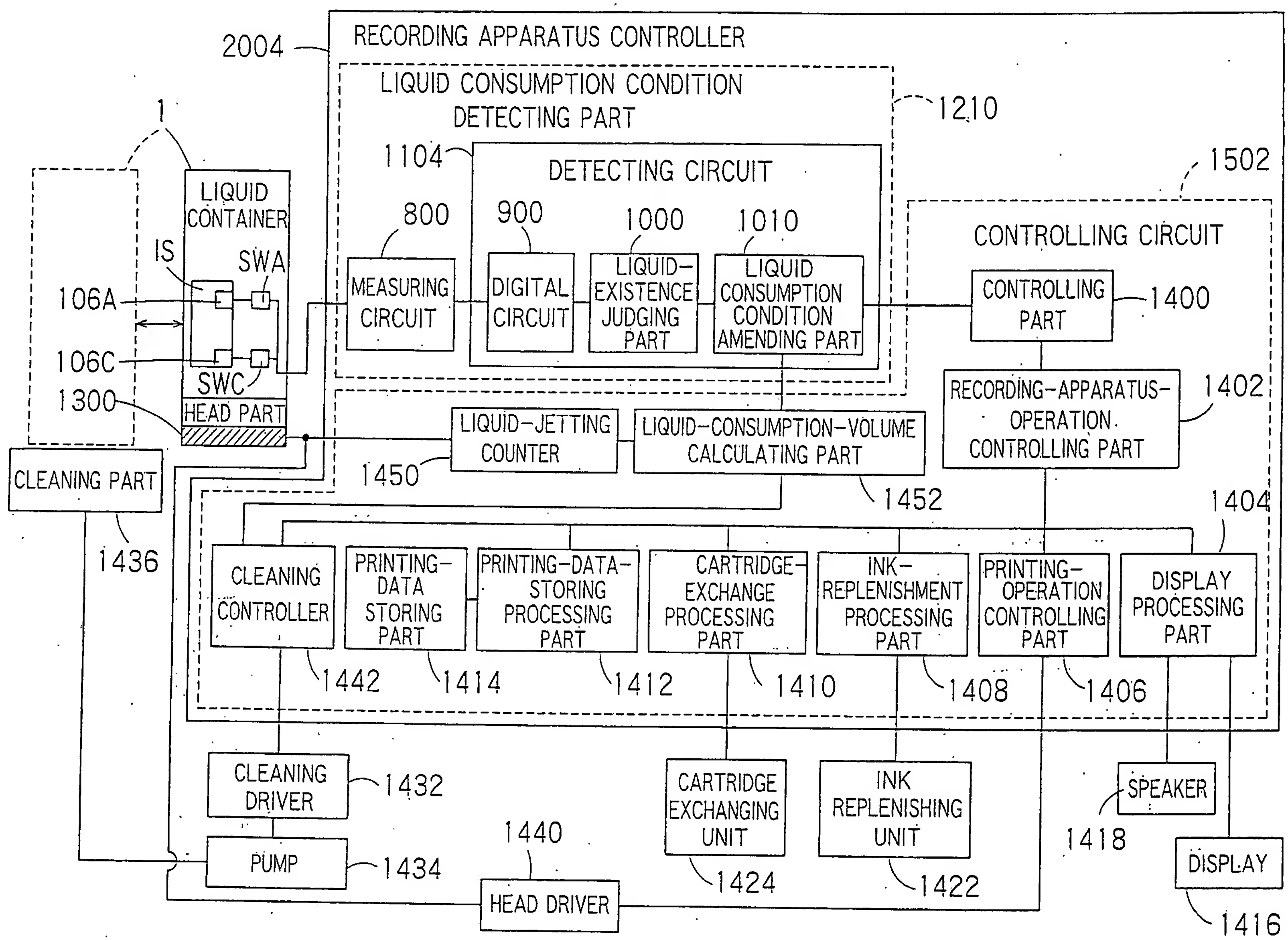
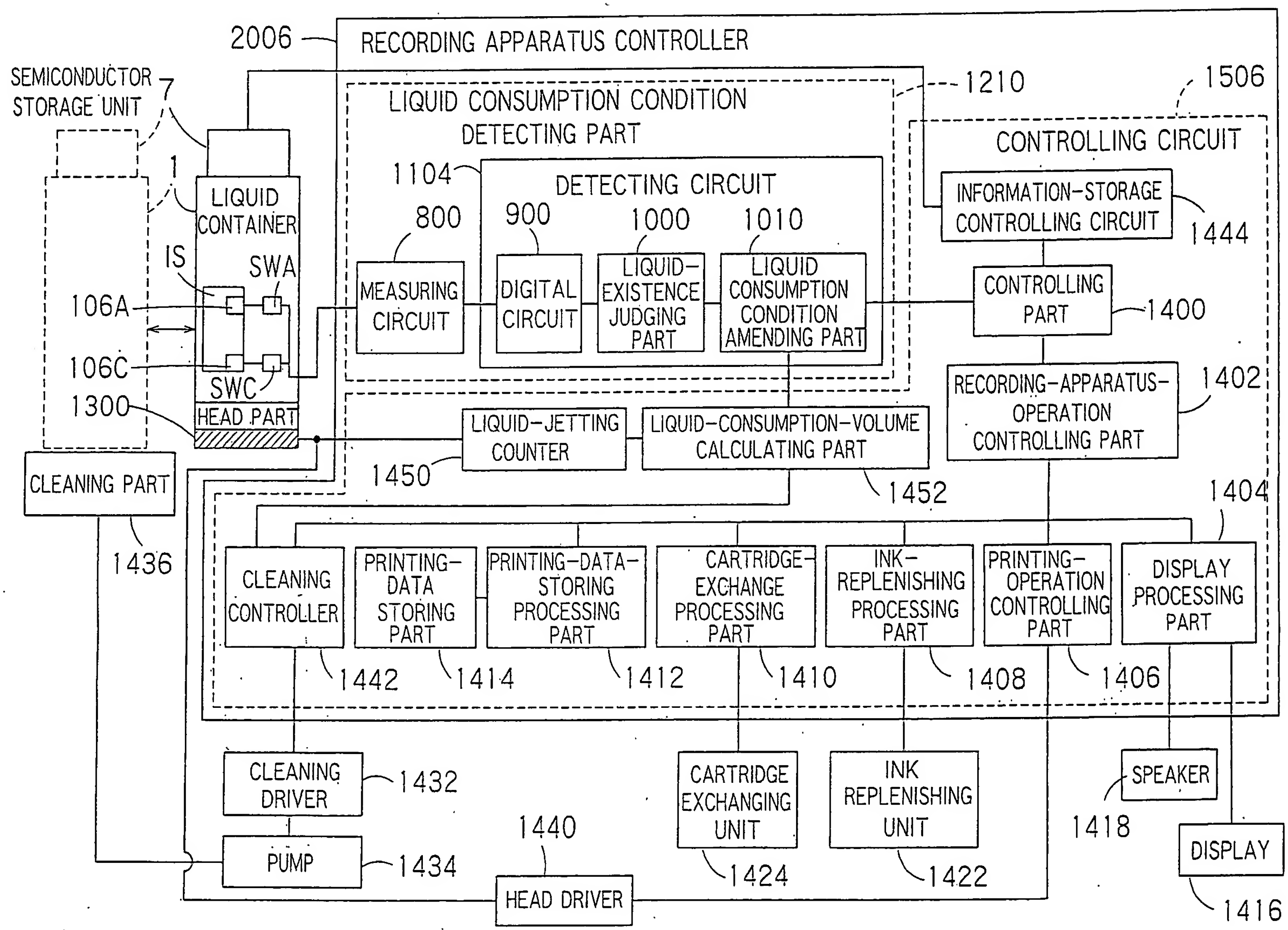

RECORDING APPARATUS CONTROLLER
2004
LIQUID CONSUMPTION CONDITION DETECTING PART
1210
DETECTING CIRCUIT
1104
MEASURING CIRCUIT
800
DIGITAL CIRCUIT
900
LIQUID-EXISTENCE JUDGING PART
1000
LIQUID CONSUMPTION CONDITION AMENDING PART
1010
CONTROLLING CIRCUIT
1502
CONTROLLING PART
1400
RECORDING-APPARATUS-OPERATION CONTROLLING PART
1402
LIQUID-JETTING COUNTER
1450
LIQUID-CONSUMPTION-VOLUME CALCULATING PART
1452
CLEANING CONTROLLER
1442
PRINTING-DATA STORING PART
1414
PRINTING-DATA-STORING PROCESSING PART
1412
CARTRIDGE-EXCHANGE PROCESSING PART
1410
INK-REPLENISHMENT PROCESSING PART
1408
PRINTING-OPERATION CONTROLLING PART
1406
DISPLAY PROCESSING PART
1404
1
LIQUID CONTAINER
IS
SWA
SWC
106A
106C
1300
HEAD PART
CLEANING PART
1436
CLEANING DRIVER
1432
PUMP
1434
HEAD DRIVER
1440
CARTRIDGE EXCHANGING UNIT
1424
INK REPLENISHING UNIT
1422
SPEAKER
1418
DISPLAY
1416

Fig. 12



2006
RECORDING APPARATUS CONTROLLER
SEMICONDUCTOR STORAGE UNIT
7
1
LIQUID CONTAINER
IS
SWA
SWC
106A
106C
1300
HEAD PART
CLEANING PART
1436
1210
LIQUID CONSUMPTION CONDITION DETECTING PART
1104
DETECTING CIRCUIT
800
MEASURING CIRCUIT
900
DIGITAL CIRCUIT
1000
LIQUID-EXISTENCE JUDGING PART
1010
LIQUID CONSUMPTION CONDITION AMENDING PART
1506
CONTROLLING CIRCUIT
INFORMATION-STORAGE CONTROLLING CIRCUIT
1444
CONTROLLING PART
1400
RECORDING-APPARATUS-OPERATION CONTROLLING PART
1402
LIQUID-JETTING COUNTER
1450
LIQUID-CONSUMPTION-VOLUME CALCULATING PART
1452
1404
CLEANING CONTROLLER
1442
PRINTING-DATA STORING PART
1414
PRINTING-DATA-STORING PROCESSING PART
1412
CARTRIDGE-EXCHANGE PROCESSING PART
1410
INK-REPLENISHING PROCESSING PART
1408
PRINTING-OPERATION CONTROLLING PART
1406
DISPLAY PROCESSING PART
CLEANING DRIVER
1432
PUMP
1434
1440
HEAD DRIVER
CARTRIDGE EXCHANGING UNIT
1424
INK REPLENISHING UNIT
1422
SPEAKER
1418
DISPLAY
1416

Fig. 13

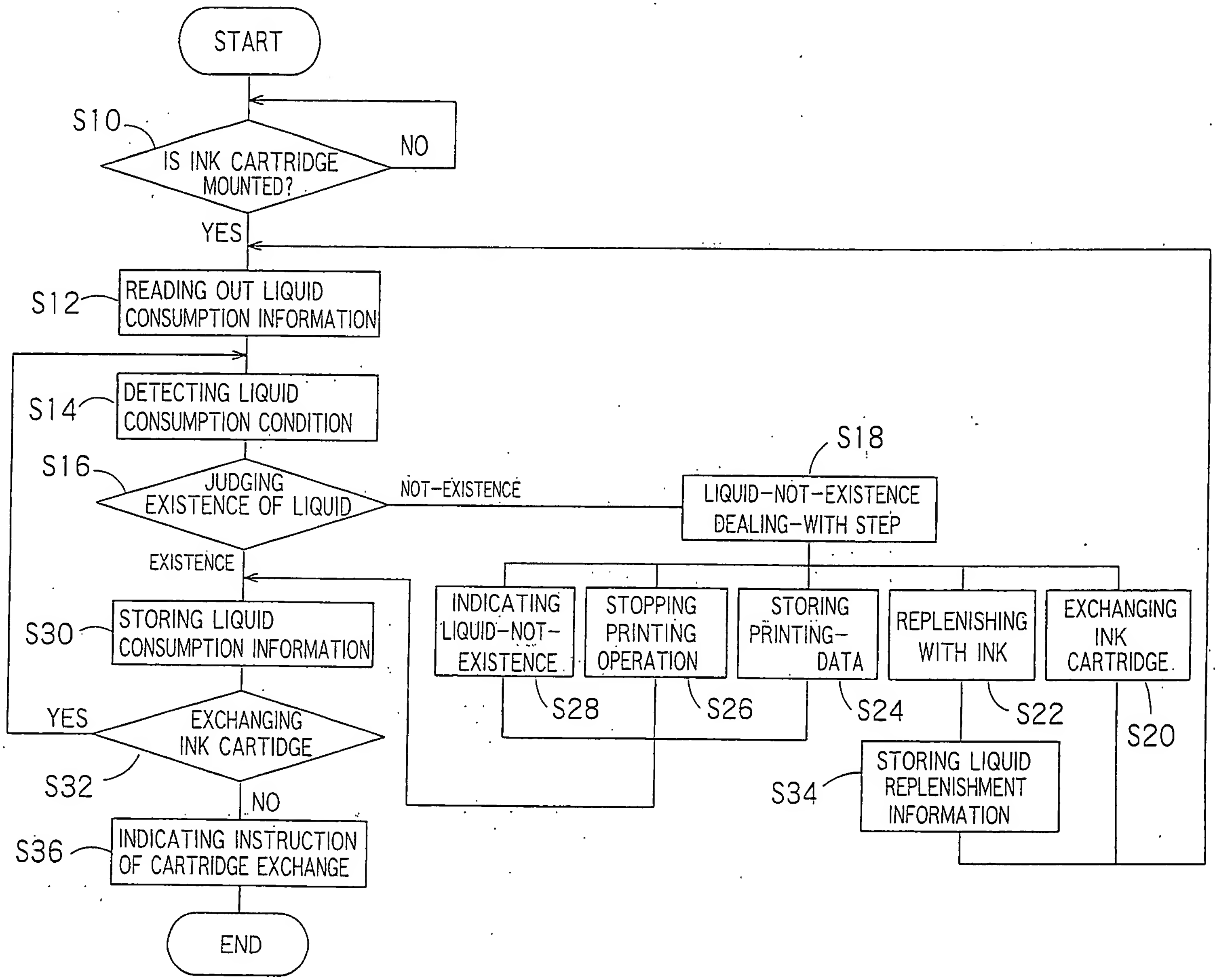
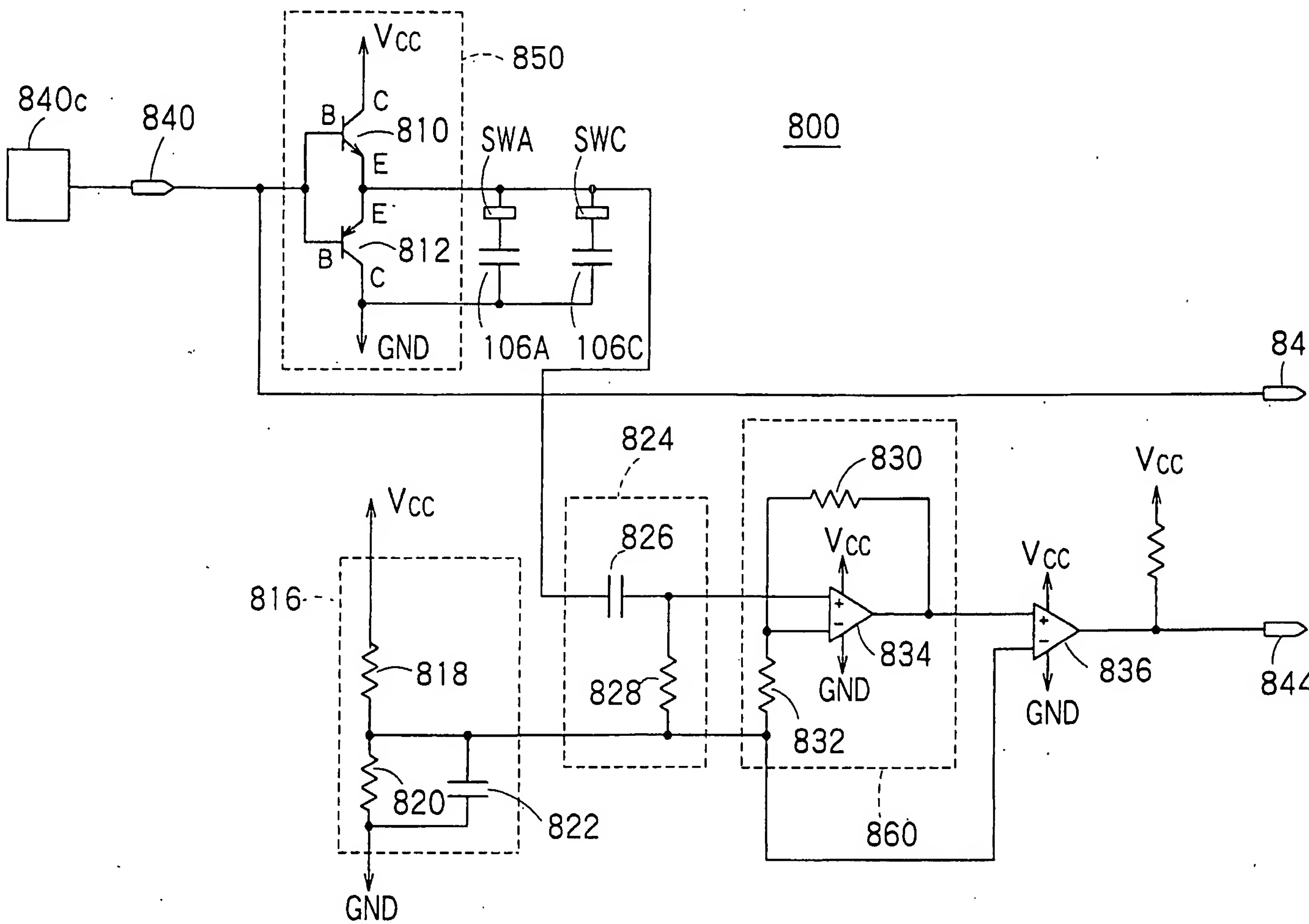

START
S10
IS INK CARTRIDGE MOUNTED?
NO
YES
S12
READING OUT LIQUID CONSUMPTION INFORMATION
S14
DETECTING LIQUID CONSUMPTION CONDITION
S16
JUDGING EXISTENCE OF LIQUID
NOT-EXISTENCE
S18
LIQUID-NOT-EXISTENCE DEALING-WITH STEP
EXISTENCE
INDICATING LIQUID-NOT-EXISTENCE
S28
STOPPING PRINTING OPERATION
S26
STORING PRINTING-DATA
S24
REPLENISHING WITH INK
S22
EXCHANGING INK CARTRIDGE
S20
STORING LIQUID REPLENISHMENT INFORMATION
S34
S30
STORING LIQUID CONSUMPTION INFORMATION
YES
EXCHANGING INK CARTIDGE
S32
NO
S36
INDICATING INSTRUCTION OF CARTRIDGE EXCHANGE
END

Fig. 14



800
840c
840
850
Vcc
C
B
810
E
E
812
B
C
GND
SWA
SWC
106A
106C
842
824
826
828
830
Vcc
834
GND
832
860
Vcc
836
GND
Vcc
844
816
Vcc
818
820
822
GND

Fig. 15

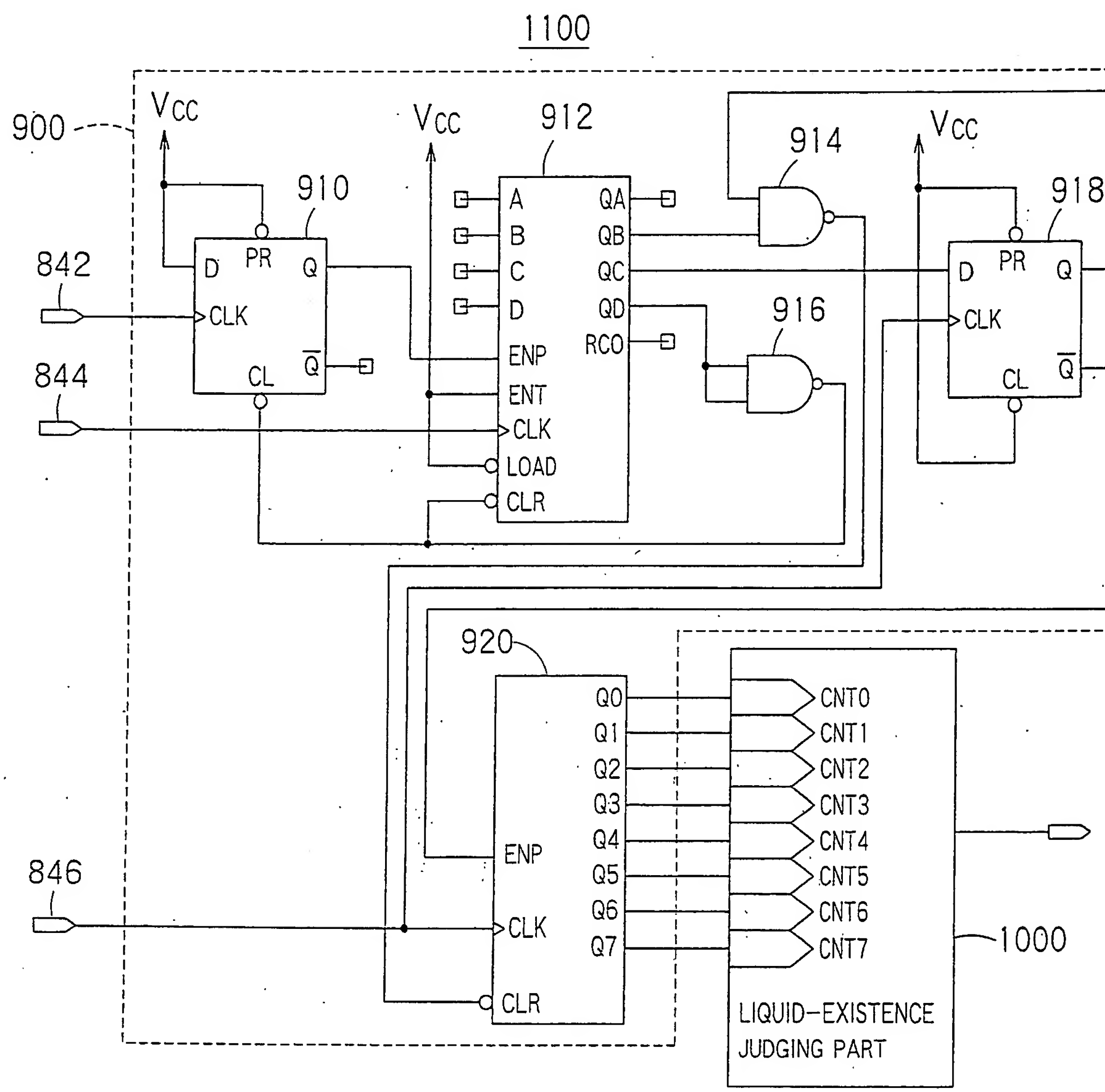

1100
900
Vcc
910
D
PR
Q
CLK
CL
Q̄
842
844
Vcc
912
A
B
C
D
ENP
ENT
CLK
LOAD
CLR
QA
QB
QC
QD
RCO
914
916
Vcc
918
D
PR
Q
CLK
CL
Q̄
920
Q0
Q1
Q2
Q3
Q4
Q5
Q6
Q7
ENP
CLK
CLR
846
CNT0
CNT1
CNT2
CNT3
CNT4
CNT5
CNT6
CNT7
LIQUID-EXISTENCE
JUDGING PART
1000

Fig. 16

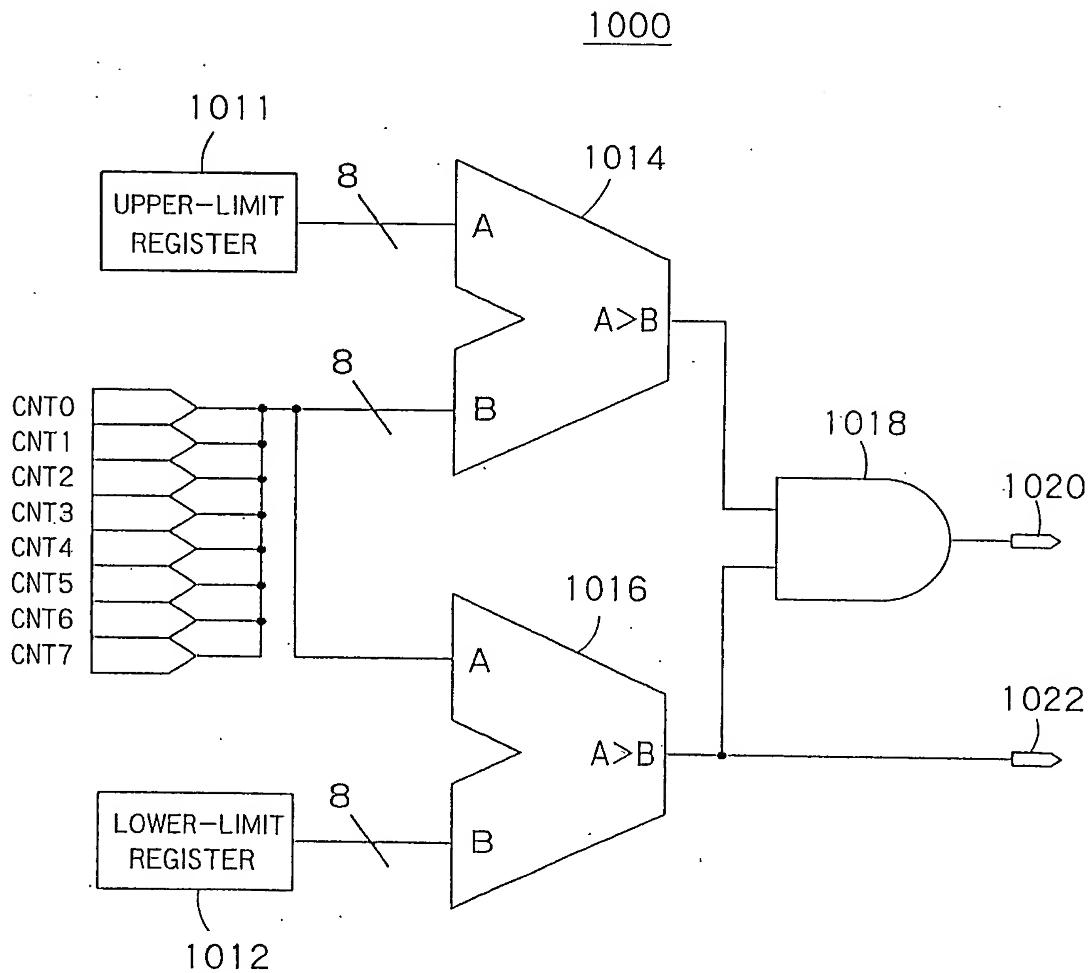

1000
1011
UPPER-LIMIT REGISTER
8
1014
A
A>B
B
8
CNT0
CNT1
CNT2
CNT3
CNT4
CNT5
CNT6
CNT7
1018
1020
1016
A
A>B
B
1022
8
LOWER-LIMIT REGISTER
1012

Fig. 17

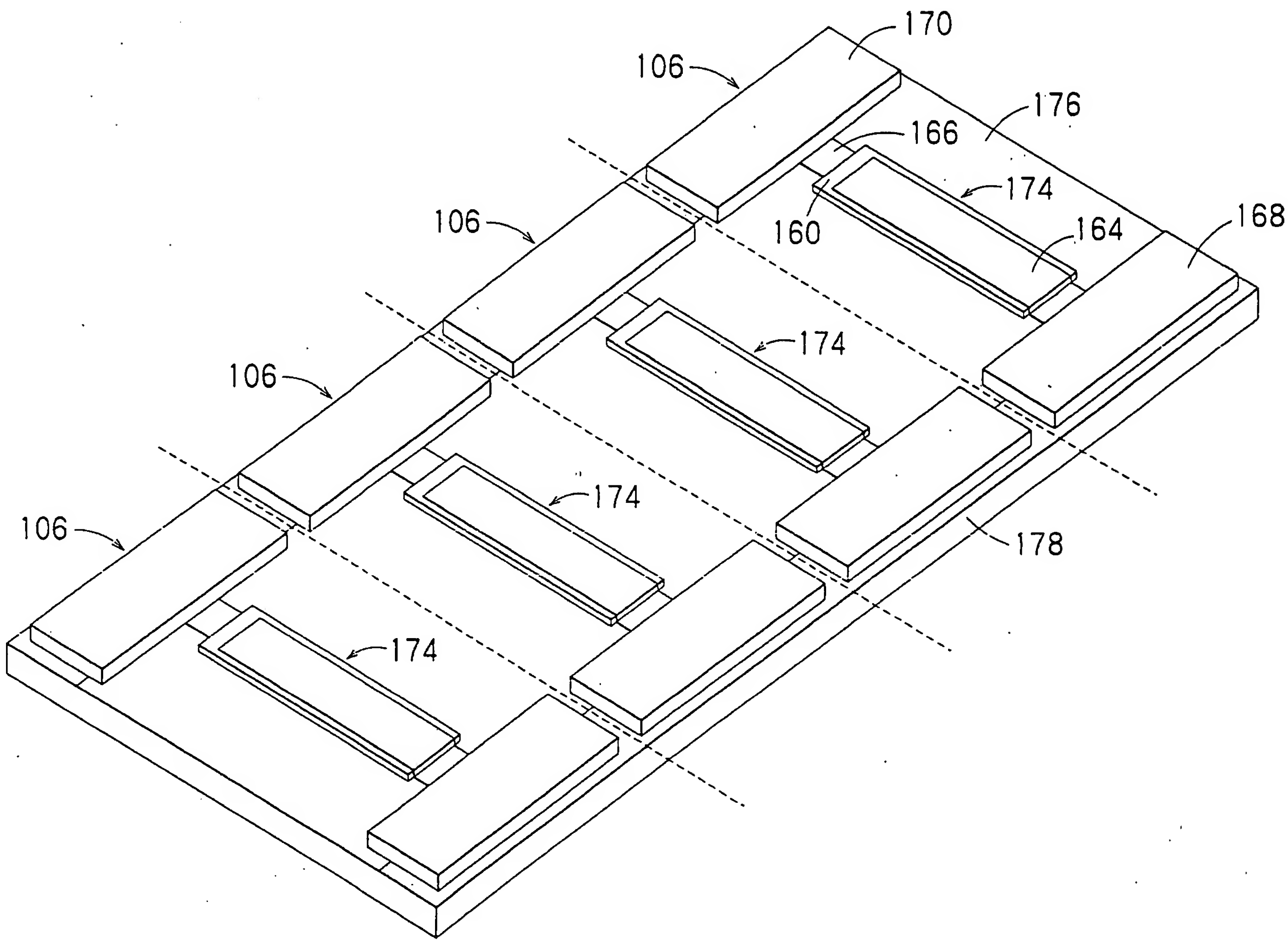
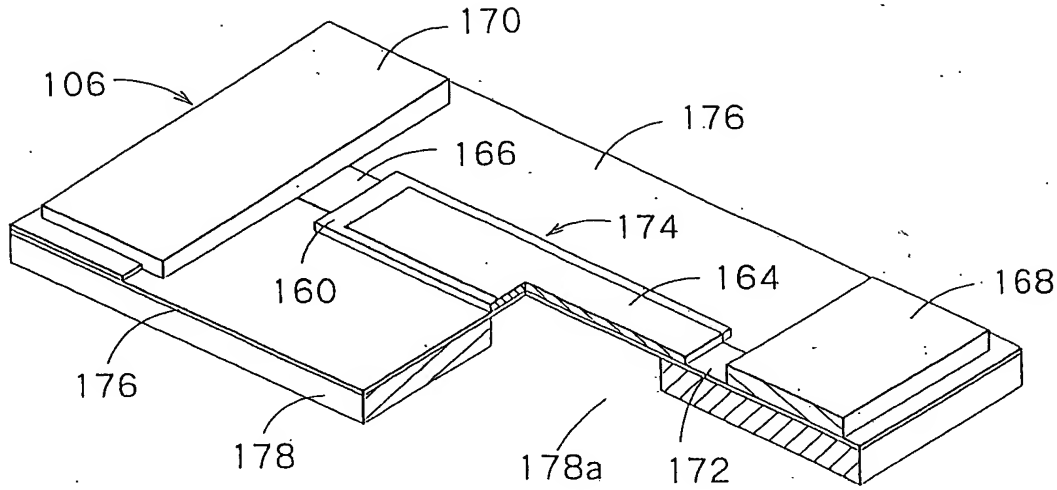
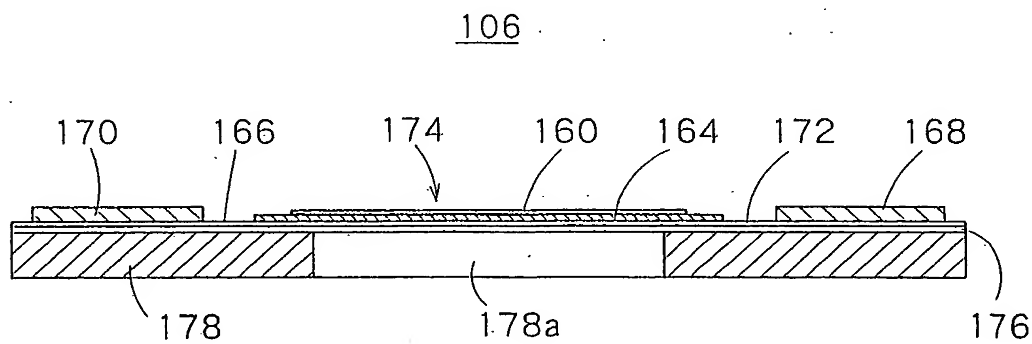


Fig. 18


170
106
176
166
174
160
164
168
176
178
178a
172
Fig. 19


106
170
166
174
160
164
172
168
178
178a
176
Fig. 20

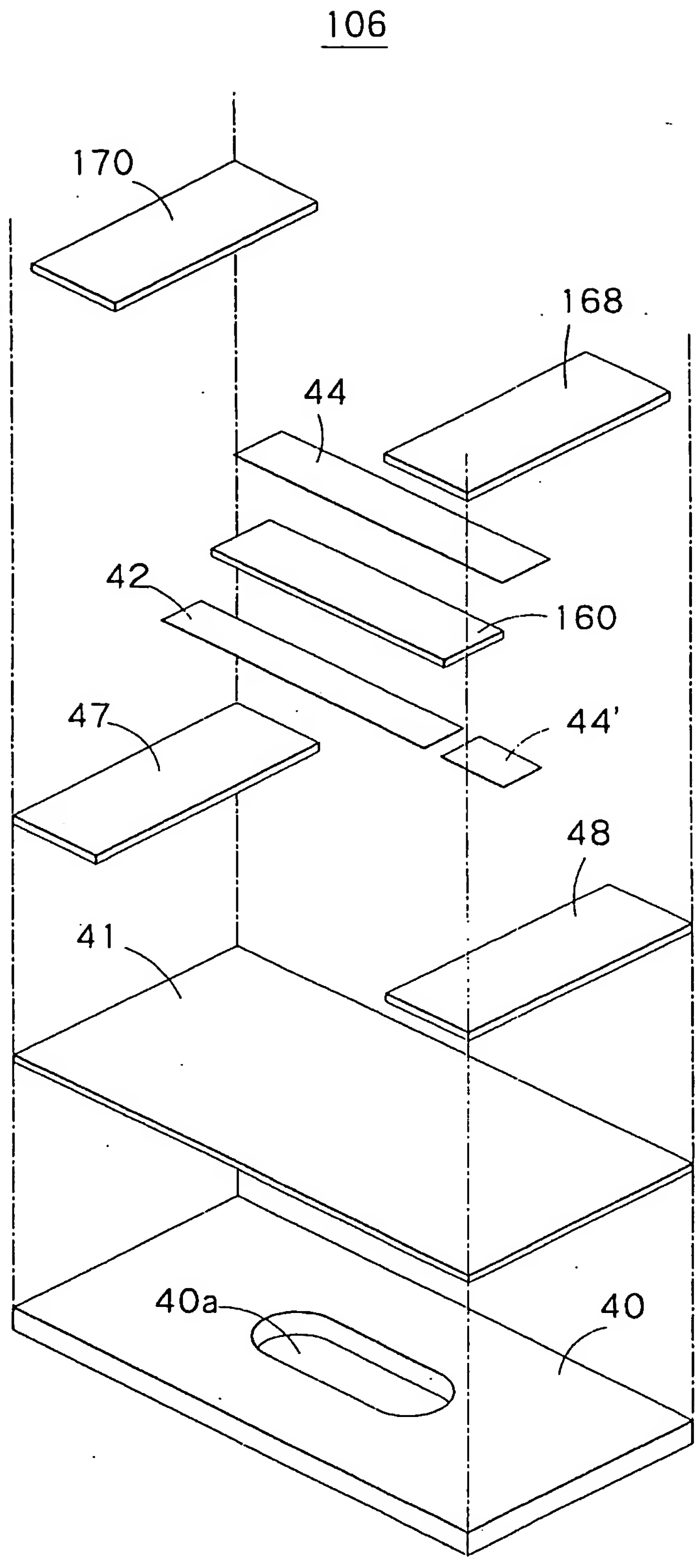


Fig. 21

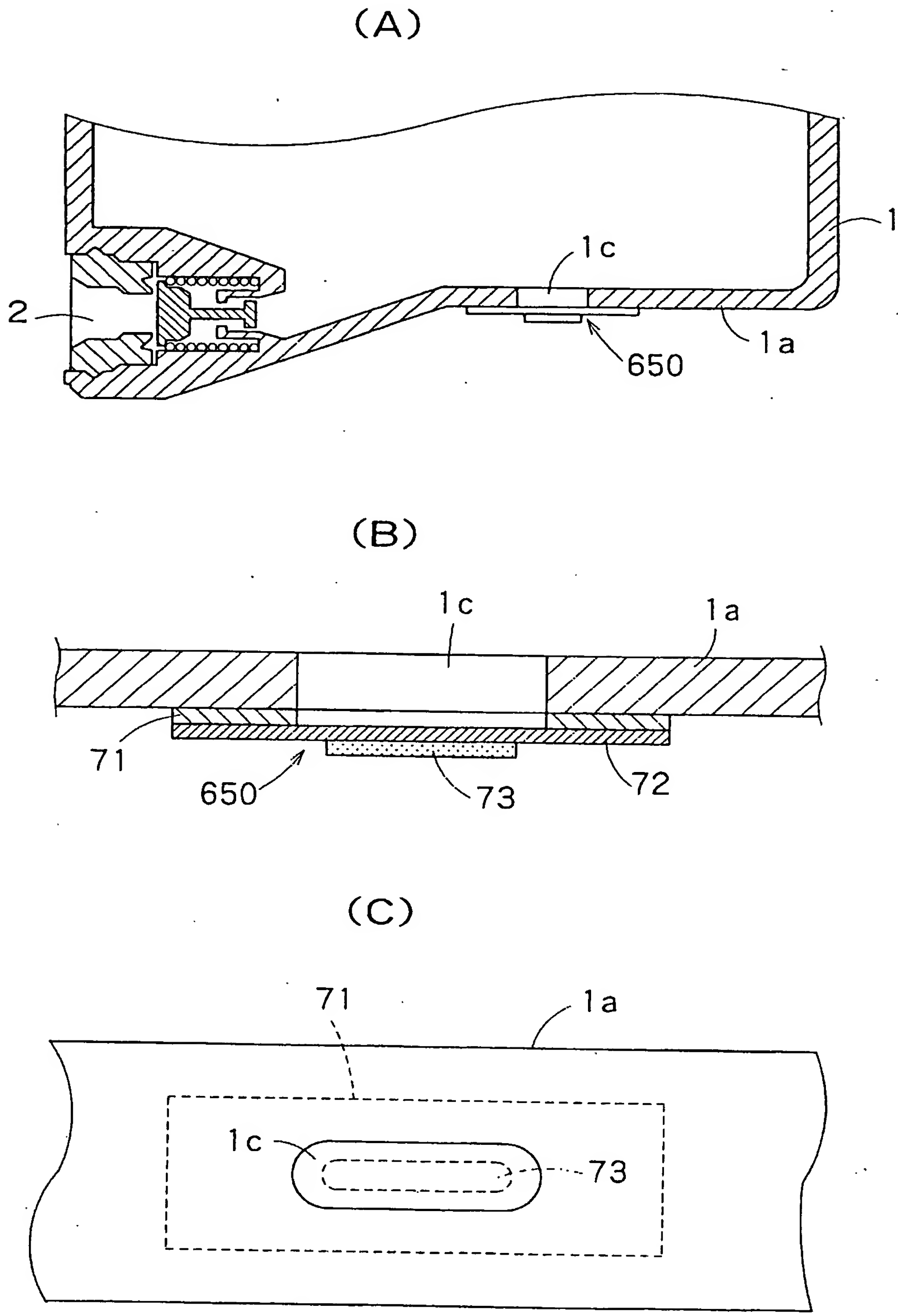


Fig. 22

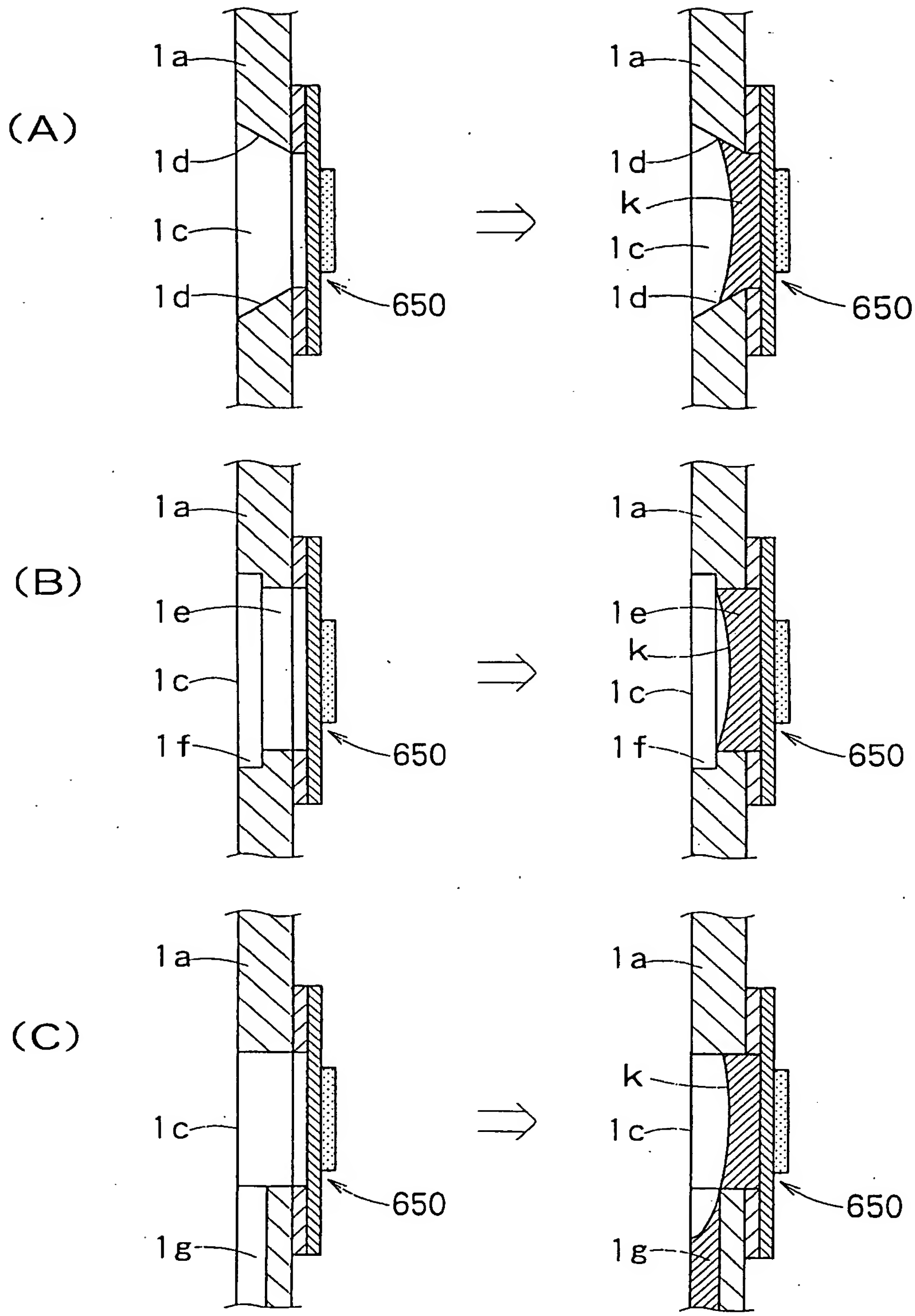

(A)
1a
1d
1c
1d
650
1a
1d
k
1c
1d
650
(B)
1a
1e
1c
1f
650
1a
1e
k
1c
1f
650
(C)
1a
1c
650
1g
1a
k
1c
650
1g

Fig. 23

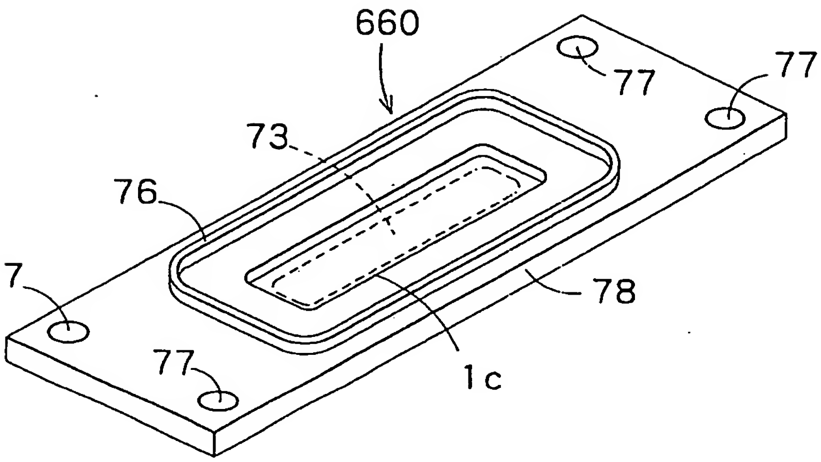
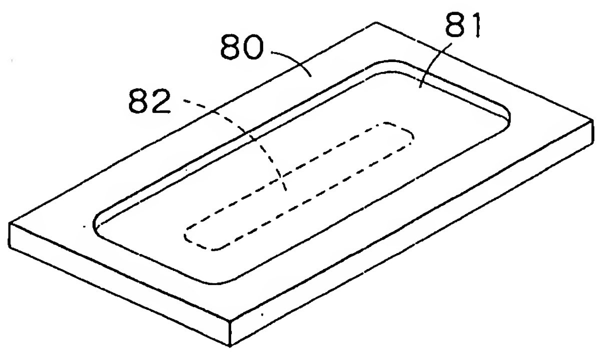


Fig. 24

(A)



(B)

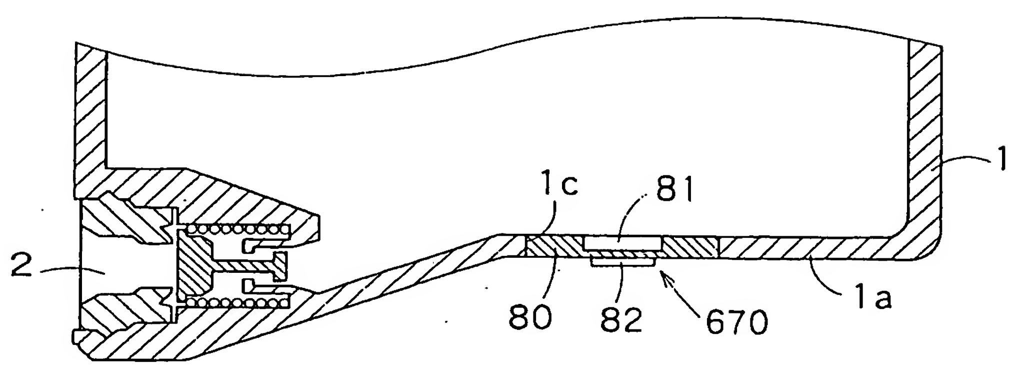


Fig. 25

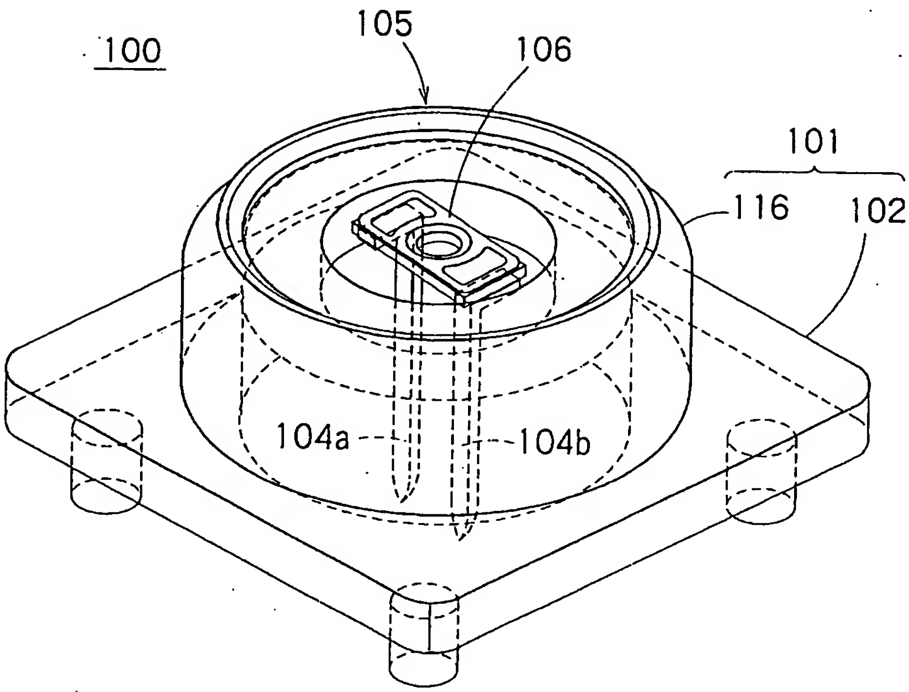


Fig. 26

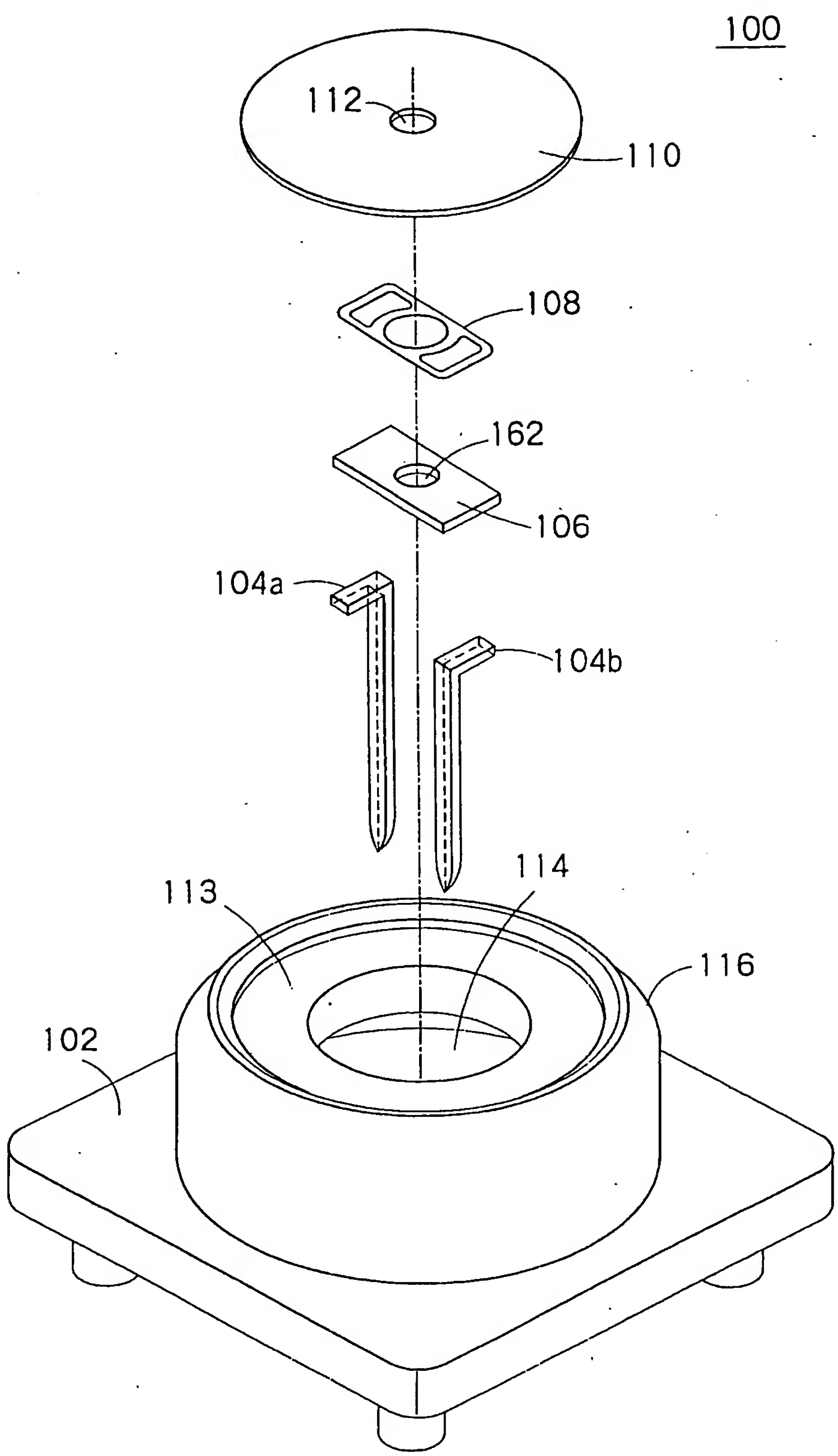


Fig. 27

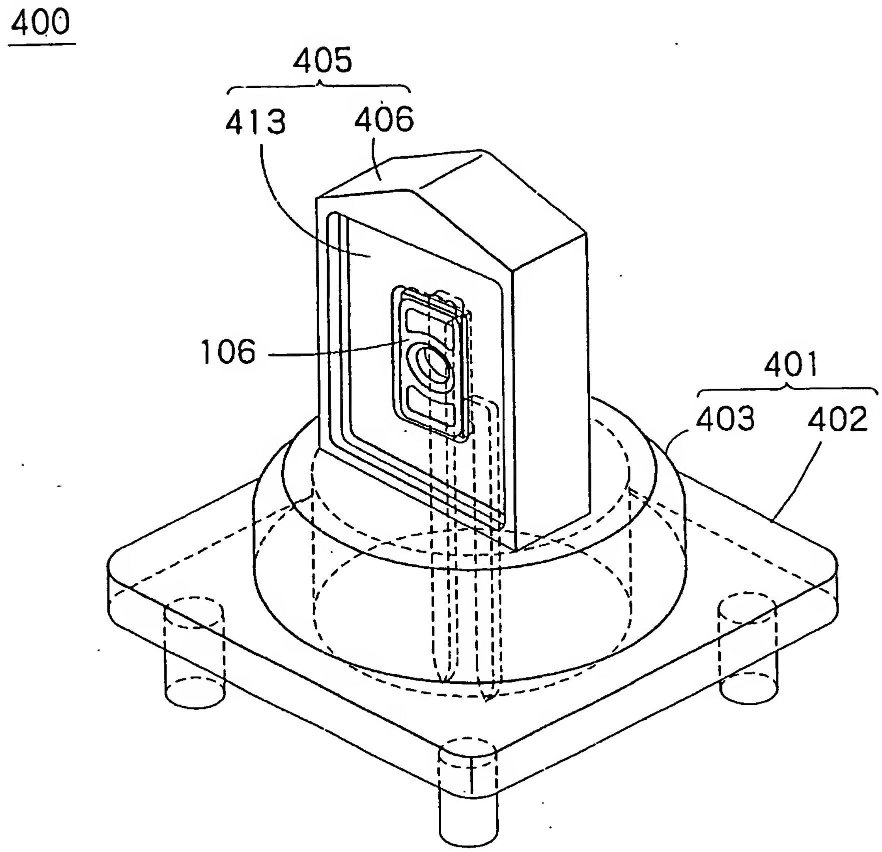


Fig. 28

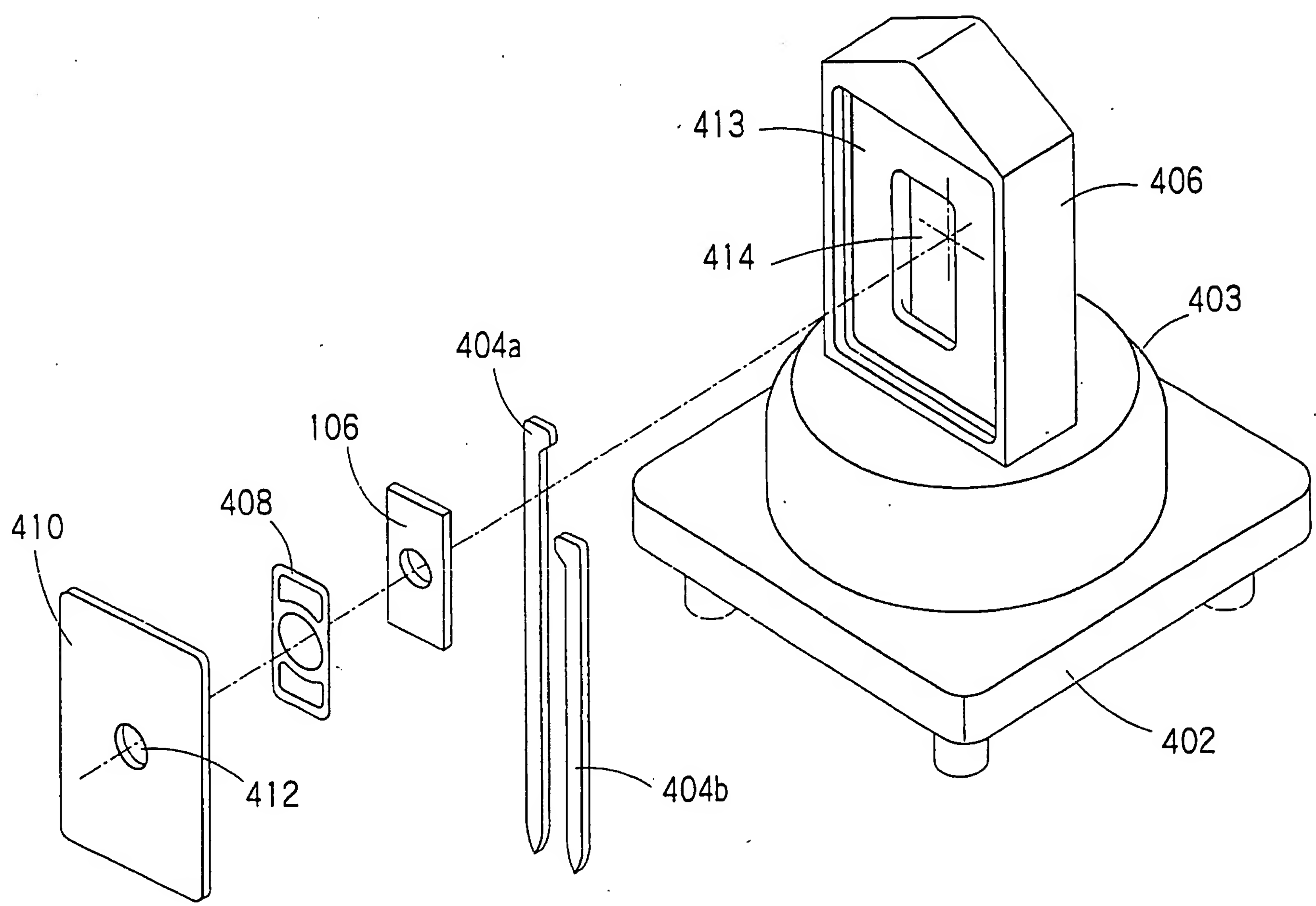


Fig. 29

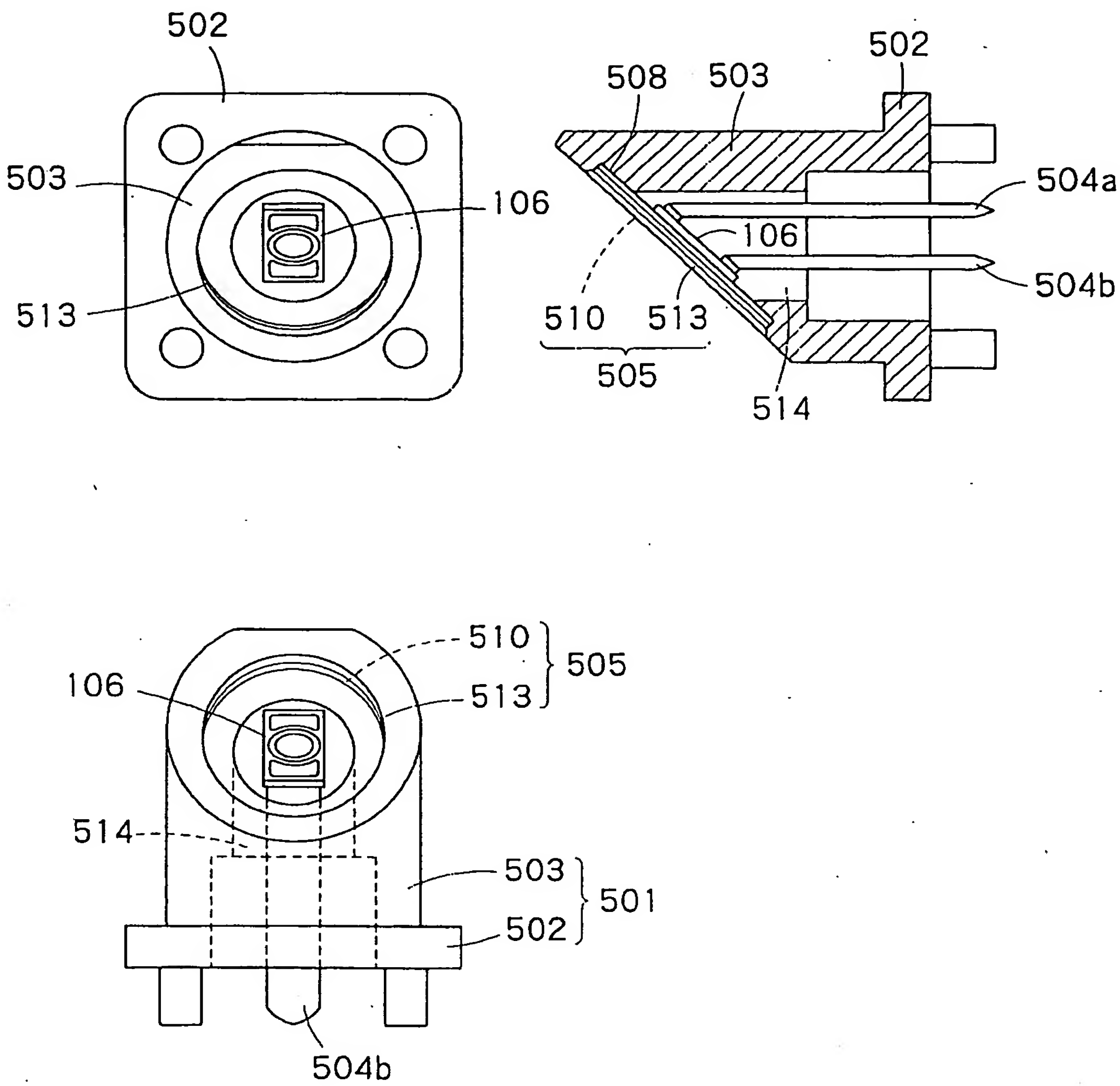

502
503
106
513
508
503
502
504a
106
504b
510
513
505
514
510
505
106
513
514
503
501
502
504b

Fig. 30

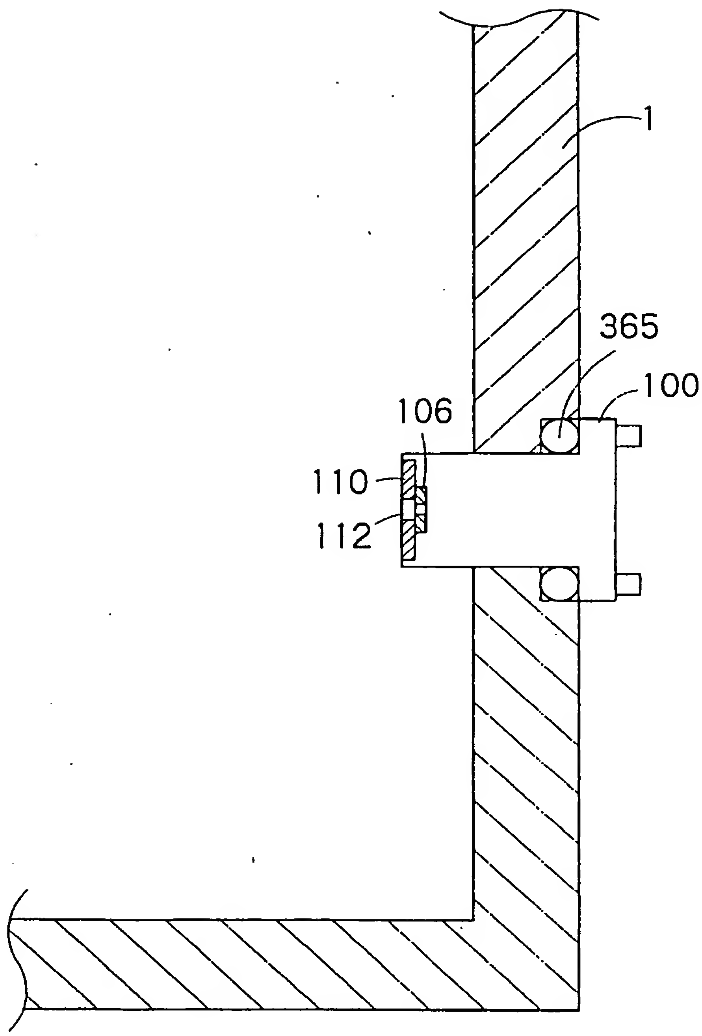


Fig. 31

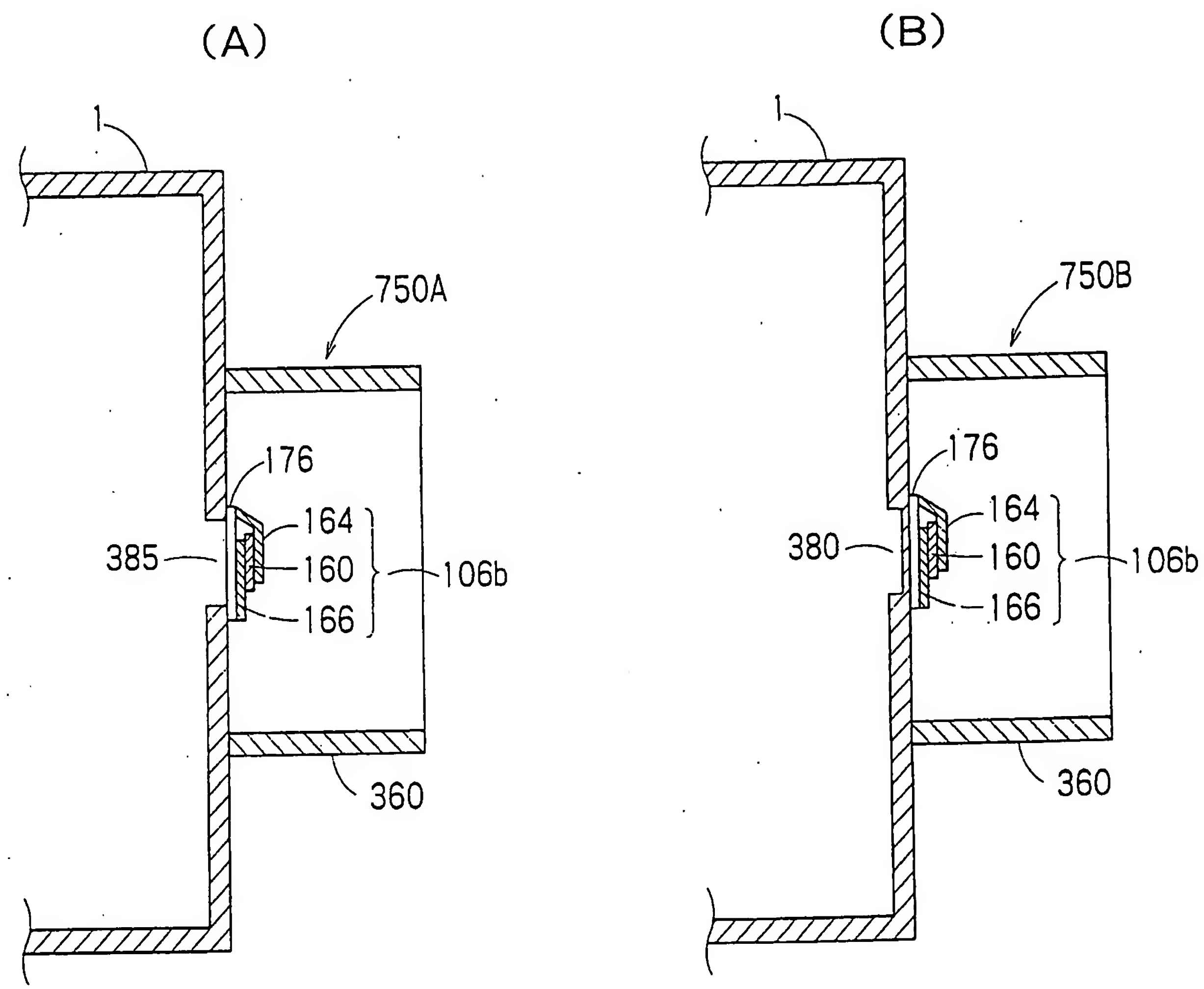
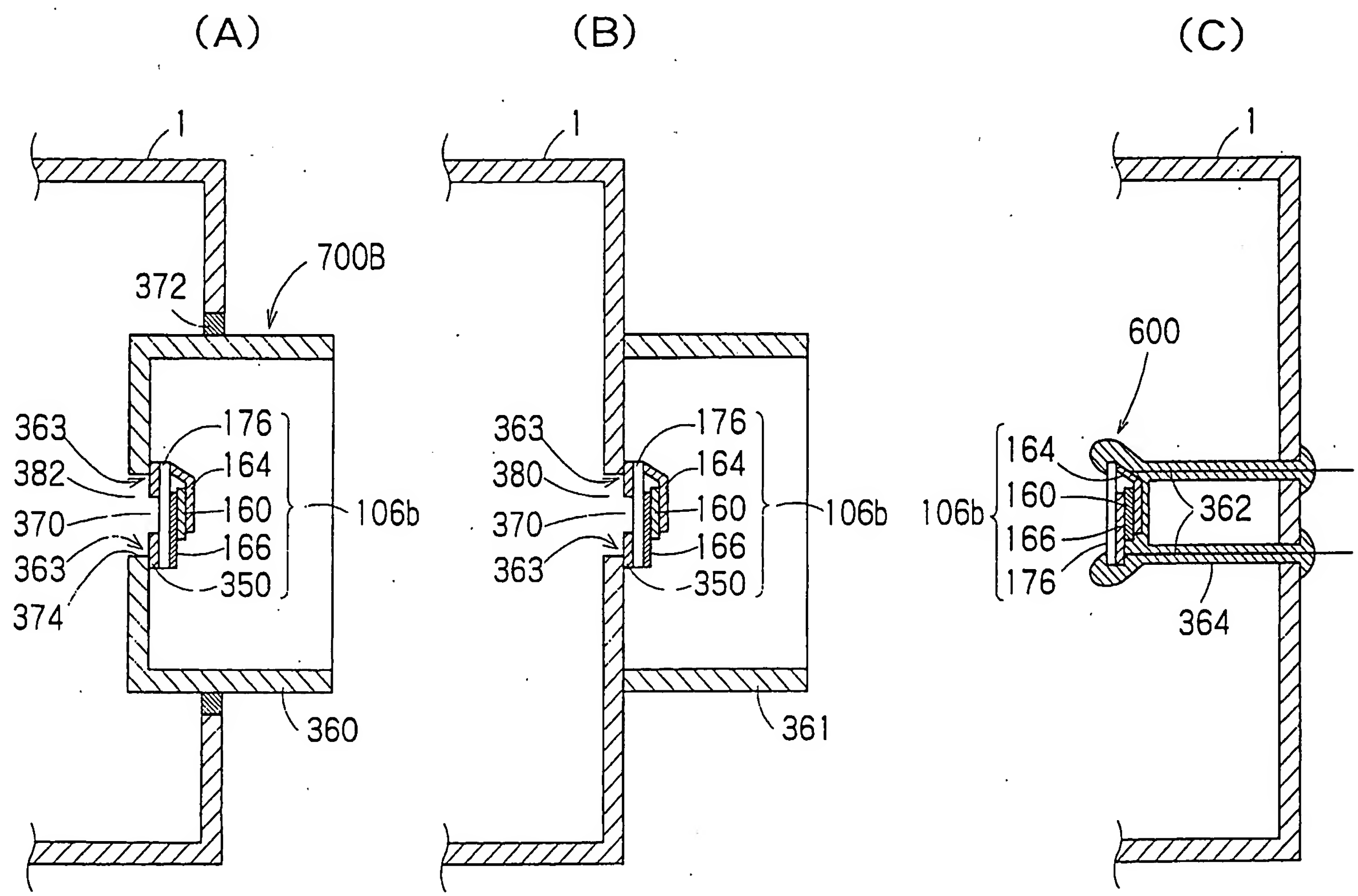

(A)
1
750A
176
164
385
160
106b
166
360
(B)
1
750B
176
164
380
160
106b
166
360

Fig. 32



(A)
(B)
(C)
1
372
700B
363
382
370
363
374
176
164
160
166
350
106b
360
1
363
380
370
363
176
164
160
166
350
106b
361
1
600
106b
164
160
166
176
362
364

Fig. 33

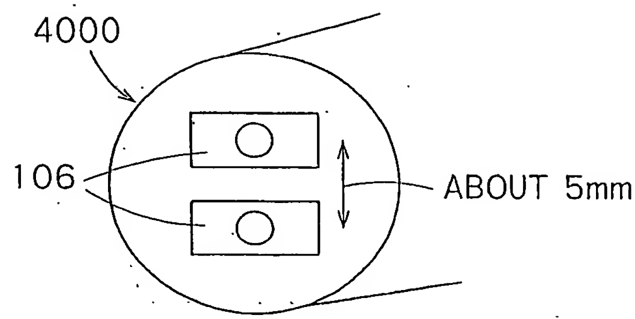


Fig. 34

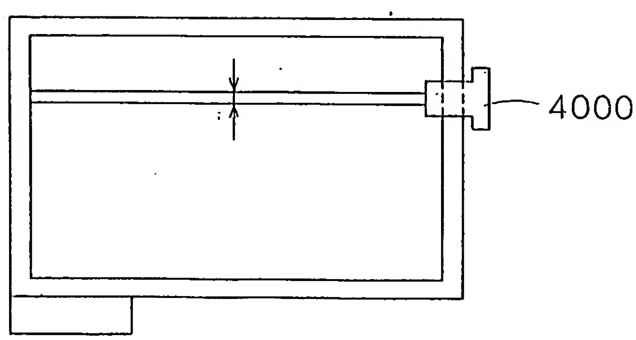


Fig. 35

[Document Type] ABSTRACT

[Abstract]

[Object]

To provide a detector of liquid consumption condition that can effectively make good use of the detection of the liquid consumption condition.

[Means for Solving the Problems]

A detector of liquid consumption condition according to the present invention includes a vibrating part that can vibrate relatively to a containing space that can be filled with a liquid, at least a portion of the vibrating part being exposed to the containing space, and a piezoelectric device that can cause the vibrating part to vibrate based on a driving signal and can generate a counter electromotive force signal by a vibration of the vibrating part. Liquid consumption condition detecting parts 1200, 1202 and 1210 detect a liquid consumption condition, based on the counter electromotive force signal from the piezoelectric device. The containing space can contain only a predetermined volume of the liquid. The vibrating part is provided in a vicinity of a liquid surface in the containing space when the containing space contains the predetermined volume of the liquid.

[Selected Drawing]

Fig. 8